STUDIES OF NATIVE ALBERTA SPECIES OF VACCINIUM

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October, 1959

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STUDIES OF NATIVE ALBERTA SPECIES OF VACCINIUM

A DISSERTATION

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ABSTRACT

The native Alberta species of Vaccinium might have potential value as fruit crops. Any improvement by way of cultural or management practices which would improve productivity would be of value to persons living in those marginal agricultural areas where such plants abound.

Four preliminary ecological studies of the native Alberta species, namely, Vaccinium canadense, Kalm., Vaccinium caespitosum, Michx., and Vaccinium vitis-idaea, L., var. minus, Lodd., were carried out.

Studies of the clonal rhizome systems of V. canadense and V. vitis-idaea var. minus indicated that environment influences their rhizome growth. The rhizomes of the two species differ in a number of respects, i.e., the majority of V. canadense shoots originate at terminal rhizome positions whereas the majority of V. vitis-idaea var. minus shoots originate at mid-rhizome positions.

The seasonal changes in leaf sap pH of both V. canadense and V. caespitosum showed similar increases with increased physiological age, however, such was not the case with V. vitis-idaea var. minus. Leaf sap pH was indicative of the species also.

Both V. canadense and V. vitis-idaea var. minus were acidophilic and showed preference for a growing medium pH range of 5.5 - 5.6.

Shoot and fruit growth studies showed that both V. canadense and V. vitis-idaea var. minus made their greatest shoot growth during

the first two weeks of the growing season. The fruit growth of V. canadense was serial, however, this was not so with V. vitis-idaea var. minus fruit growth.

Vegetative propagation investigations showed that both V. canadense and V. vitis-idaea var. minus may be propagated by rhizome cuttings. V. canadense rhizomes showed better growth when their shoots were removed by pruning.

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INTRODUCTION

A number of the Vaccinium species found growing in eastern Canada and the northeastern United States have become commercially important fruit crops. It is quite possible that the native Alberta species as well might have potential value in this regard. Certainly anything by way of cultural or management practices that would increase productivity would be of value to people presently living in those marginal agricultural areas where such plants abound.

This investigation involves four preliminary ecological studies of the native Alberta species of Vaccinium namely: Vaccinium canadense, Kalm., the Canada blueberry and Vaccinium caespitosum, Michx., the dwarf bilberry, two lowbush blueberries, and Vaccinium vitis-idaea, L., var. minus, Lodd., the upland cranberry.

The objectives were:

(1) to determine, by mapping, the characteristics and growth habits of clonal rhizome systems of both V. canadense and V. vitis-idaea var. minus in relation to their environment.

(2) (a) to show the seasonal changes and the possible influences of environment on the leaf sap reaction of V. canadense, V. caespitosum and V. vitis-idaea var. minus.

(b) to investigate the acidophilic nature of V. canadense and V. vitis-idaea var. minus.

(3) to determine the seasonal pattern of shoot and fruit growth of V. canadense and V. vitis-idaea var. minus and to relate the growth pattern to environmental influences.

(4) to investigate the possibilities of vegetative propagation of *V. canadense* and *V. vitis-idaea* var. *minus* by rhizome cuttings subjected to shoot pruning and to determine the possible influence of environment on regeneration.

An insight into these factors would be of assistance in evaluating the potentialities of the species concerned and of value as directives for further investigations.

LITERATURE REVIEW

1. Clonal Rhizome Studies

Stallard (16) reporting on secondary succession in forest formations of Minnesota found by tracing the extensions of Vaccinium canadense and V. pennsylvanicum rhizomes that they often exceed several yards in length. A colony of apparently separate plants may be the branch members of a single individual. He suggested that this was the means of regeneration and migration of these species.

Trevett (19) studied the effects of burning as a pruning technique on lowbush blueberry fields of Vaccinium canadense and V. angustifolium. He suggested that a vigorous rhizome system was the key to a continuing high level of productivity because rhizomes were involved directly or indirectly in all clonal functions. The bulk of the underground parts of the blueberries were located in the surface organic and soil horizons. He stated that the organic horizons contained the bulk of the rhizomes, not so much because penetration of the mineral horizons was impossible, but because the organic layer provided both a favorable physical, chemical and biological environment and a path of least resistance. The area occupied by a clone could be extended further when new rhizomes develop either laterally from a plant or from the original rhizome. Trevett also noted that the majority of above ground stems appeared to originate from the ends of rhizomes rather than from other locations. Exceptions to this occurred if the field concerned had a

relatively thick organic horizon, in which case stems would originate along the entire length of the rhizome. New stem development was found to originate from rhizomes which were relatively close to the soil surface. Trevett suggested that the transition from rhizome to shoot occurs where it does because of light or an associated stimulus, catalyzing the differentiation and growth of buds.

Excavation of clonal rhizomes of Vaccinium angustifolium var. laevifolium by Hall (9) revealed the presence of a tapering structure growing vertically in the soil. Microscopic examination showed that this structure was a typical tap root. This root which was considered to be a continuation of the primary root of the original seedling plant was found to be common to all native lowbush blueberries. Hall stated that since the tap roots of older plants have been found three feet below ground level, their function during periods of dry weather may be to supply the blueberry plants with water and soil nutrients not available in the area of the rhizomes. He suggested that too much stress has been placed on the role of rhizomes in the nutrition of lowbush blueberries.

MATERIALS AND METHODS

1. Clonal Rhizome Studies

During June, 1956, six sites of varied slope, vegetational cover and soil moisture conditions were chosen at the University Native Fruit Station. The elevations of the area involved approximates 3,240 feet above sea level and is topographically hilly. The sites were located at varying local elevations; their relative positions have been designated as being high, medium or low (differences of approximately 30 feet in elevation). The sites were of the following characteristics:

Site 1. A 40° slope facing 26° east of north, of high elevation, moderate shade conditions and abundant soil moisture. Clones of V. canadense, V. caespitosum, and V. vitis-idaea var. minus were distributed along the bottom 1/3 of the slope.

Site 2. A 10° slope facing south, of medium elevation with moderate shade conditions. Clones of V. canadense and V. vitis-idaea var. minus were distributed over the entire area.

Site 3. A 3° slope facing 56° east of north of medium elevation with heavy shade conditions. Clones of V. canadense, V. caespitosum and V. vitis-idaea var. minus were distributed over the entire area.

Site 4. A 2° slope facing west, of low elevation with heavy shade conditions and abundant soil moisture, situated along the edge of a sphagnum bog. Clones of V. canadense, V. caespitosum and V. vitis-idaea var. minus were distributed over the entire area.

Site 5. A 3° slope facing 70° east of north, of high elevation and with large tree cover almost absent. Clones of V. canadense, V.

caespitosum and V. vitis-idaea var. minus were distributed over the entire area.

Site 6. A 20° slope facing south of high elevation with large tree cover absent. Clones of V. canadense present but few in number.

An area approximately 30 meters square was marked with stakes at each site during July, 1956, to delimit the sites to as uniform conditions of slope, shade, elevation and soil moisture as possible. Preliminary examination of clonal rhizomes of V. canadense and V. vitis-idaea var. minus were made at this time to develop satisfactory methods of mapping.

A vegetational analysis of each site was carried out during the spring and summer of 1957. The tall tree and shrub stratas were sampled from 3 randomly selected 10 meter square quadrats. The lower strata composed of small woody shrubs and herbaceous plants was sampled from 5 randomly selected 1 square meter quadrats. Quantitative data on density, coverage, frequency and dominance, and qualitative data on sociability and vitality were recorded at this time to describe the vegetational character of the areas studied. Density indicates the relative importance of a species at a site based upon abundance on a unit-area basis. The data on density represents an average of the actual numbers of each species per quadrat. Coverage indicates the relative importance of a species with regard to size of plant or area occupied. The data recorded is a visual estimate of the percentage of area covered by each species and is expressed as a number between 1 and 5.

(1) less than 5% of ground surface.

(2) 5 to 25% of ground surface.

(3) 25 to 50% of ground surface.

(4) 50 to 75% of ground surface.

(5) 75 to 100% of ground surface.

Frequency denotes the distribution of a species over the site being sampled. The data is an expression of the percentage of quadrat samples in which a species occurs and is presented as a number between 1 and 5.

(1) 0 - 20%

(2) 20 - 40%

(3) 40 - 60%

(4) 60 - 80%

(5) 80 - 100%

Species having frequency ratings of 5 and which have been observed as important for their particular strata were designated as dominants. Sociability indicates the growth habit of the various species. Those forming colonies, clone groups or surface mats were noted, otherwise the species existed as single plants. The evaluation for vitality indicates apparent adaptation and is of assistance in designating the importance of certain species. A number from 1 to 3 was assigned each species on the basis of the following:

(1) plants existing but not increasing in numbers.

(2) plants maintained and increased by vegetative means but not completing their annual cycle of growth and development.

(3) well developed plants completing their annual cycle of growth and development.

After completion of the vegetational analysis, mapping of the clonal rhizomes of V. canadense and V. vitis-idaea var. minus was undertaken at the various sites. Three clones of V. canadense were selected at each site and three clones of V. vitis-idaea var. minus were also selected at each site except Site 6. Beginning at Site 1 the extraneous surface material was removed from the clonal plant selected. By carefully clearing and cutting away roots and stems of other plants and the top organic layer of the soil, the rhizome was excavated 10 cm. sections at a time, care being taken to avoid changing the original position of the structure or its appendages. After each section was uncovered, changes in direction of the rhizome were noted, their positions being determined with a "Silva" hand compass. The length, diameter and depth of the rhizomes were determined in cm. using a set of vernier calipers. Morphological characteristics of shoots at the soil surface, rhizome growing points, major root locations, dead shoots and decayed rhizome ends were also noted. As these data were gathered a field map was prepared by plotting the direction of the rhizome and recording the necessary data. The rhizome maps were plotted on standard cross section drawing paper to a scale of 1 cm. equal to 5 cm. actual distance. This procedure of mapping was carried out for the clones at all sites. A total of 18 maps of V. canadense and 15 maps of V. vitis-idaea var. minus were prepared. Final maps were prepared from the field maps during the winter of 1958-59 on tracing paper to a scale of 1 cm. equal to 2 cm. actual distance. Data on the clonal characteristics of rhizome depth, length,

diameter, numbers of shoots, depth of shoot origin, position of shoots in relation to the rhizome, numbers of rhizome growing points, major root locations, dead shoots and decayed rhizome ends was taken from the maps and tabulated to facilitate rapid comparison. Major roots are those which range in diameter from 0.01 to 0.05 cm. at their point of origin on the rhizome. After completing the excavation and mapping, each clone was bagged and labeled. All the clones were taken to the laboratory and oven-dry weight in gms. of roots, rhizomes and plants were determined for each clone. Representative soil profiles were described and soil samples removed during August, 1957, from each site. Profile description involved horizon, designation, depth, color, structure and texture. The soil samples were taken to the laboratory, air dried and passed through a 5 mm. sieve. Chemical analyses of these samples were made during the fall of 1958 using the Spurway method (18).

RESULTS

1. Clonal Rhizome Studies

(a) Relationships of *Vaccinium* species to the vegetation at the various sites

Results of the vegetational analysis (Tables 1 to 6 in the Appendix) show that species present, number of species, and number of clones within species differs markedly between sites.

The data on the tall tree strata are given in Table 1.

Table 1. Density and coverage, tall tree strata, at sites 1 to 6, based upon an average of three 10 x 10 quadrats

Site	1	2	3	4	5	6
Density	27	12	32	28	5	4
Coverage	5	3	5	5	2	1

By comparing the data on density with that of coverage it will be noted that the heaviest tree cover existed at Site 3 while the lightest occurred at Site 6.

Certain plants were common at all locations and did not appear to show particular preference for a specific environment. These included *Populus tremuloides*, *Shepherdia canadensis*, *Maianthemum canadense*, *Rosa acicularis*, *Lathyrus venosa*, *Elymus canadensis* and *Spiraea alba*. Other species proved to be quite selective with regard to light and soil moisture. Vegetational analysis data show the

preference of the following species for abundant soil moisture and shade: Larix laricina, Ledum groenlandicum, Cornus canadensis, Pyrola secunda, Selaginella spp. and Sphagnum spp. The species - Larix laricina, Ledum groenlandicum, Selaginella spp. and Sphagnum spp. were present in the greatest numbers at the sites of heavy shade, low elevation and abundant soil moisture. Cornus canadensis and Pyrola secunda were found at the heavily shaded sites regardless of elevation. Species showing a preference for exposed conditions included the following: Arctostaphylos uva-ursi, Aster frondeus and Erigeron drummondi. The data on density (Tables 1 - 6 in the Appendix) show the preference of Arctostaphylos uva-ursi for an open dry environment. This plant was absent at Site 3 where the heaviest tree cover existed and in greatest abundance at the open southern exposure of Site 6.

The Vaccinium species were important in the composition of the low shrub and herbaceous strata at all sites except the open, south facing slope of Site 6. The data on density for the three species V. canadense, the Canada blueberry, V. caespitosum, the dwarf bilberry, and V. vitis-idaea var. minus, the upland cranberry, (Table 2) shows the influence of habitat on their abundance. V. canadense shows the greatest degree of adaptability of the three species by its presence at all six sites. It was present in greatest numbers at the relatively open conditions and high elevation of Site 5. This would suggest that it is best adapted to such an environment but edaphic conditions may have had an influence. The suggested influence of edaphic conditions of soil pH and depth of organic horizons is discussed in another section (pages 14 and 15). Conditions of moderate to heavy shade and good

soil moisture, irrespective of elevation appeared to be contributing factors influencing the abundance of V. canadense.

Table 2. The density of Vaccinium species at sites 1 to 6

Species	Site 1	2	3	4	5	6
V. canadense	45	39	57	63	75	22
V. vitis-idaea var. minus	287	407	144	102	190	nil
V. caespitosum	12	nil	45	43	36	nil

Shade (Table 1) and the interacting influence of soil moisture seemed of more importance to V. vitis-idaea var. minus than it was to V. canadense. V. vitis-idaea var. minus was found in greatest abundance at the sites of moderate to heavy shade but was nonexistent at the open, south facing slope of Site 6. The great increase in abundance of this species at Site 2 appeared to be related to its growth habit as well as a lack of competition from other plants. At this site it formed very dense colonies. Elevation had no apparent influence on its abundance.

The species V. caespitosum was not present at all sites but was present in greatest abundance where heavy shade existed. Colonies were found growing beneath the cover of larger herbaceous plants and woody shrubs. Where this type of cover was not abundant as at sites 2 and 6, V. caespitosum was nonexistent.

A maximum limit of shading was also indicated for the three Vaccinium species. Under the most heavily shaded conditions

which existed in certain areas at Site 3 all three species indicated that they were not completing a regular annual developmental cycle and were existing in a vegetative condition.

(b) The influence of edaphic conditions on the distribution of *Vaccinium* species at the various sites

The soil survey carried out by the Experimental Farm Service, Canada Department of Agriculture, Edmonton, of the Rocky Mountain House district of Alberta (soil survey report not published) classifies the soil of the Native Fruit Station as follows:

(1) Podzolic grey wooded. Prentice loamy sand. This type is found at the higher elevations and slopes.
(2) Organic. Sedge and Mosspeat. This type is found at the low elevations in sedge or moss bogs.

The description of representative soil profiles of Sites 1 to 6 are presented in Table 7 in the Appendix. The upper horizons are quite variable in depth between sites. The organic horizons at Site 5 reached a depth of 10 cm. which was considerably more than at the other sites. The increase in abundance of *V. canadense* at this relatively open site was believed to be influenced by this since deep organic horizons appear to provide very good environmental conditions for the subsurface rhizomes and roots. On this basis it might be argued that the comparatively shallow depth of the organic horizon at Site 6 was responsible for the relative lack of *Vaccinium* species in this part of the experimental area.

Because differences in abundance of the *Vaccinium* species could have been influenced by a difference in soil nutrient levels, analyses of soil samples from all sites were carried out. The results (Table 8 in the Appendix) show no marked differences in nutrient levels

between sites. The pH of the upper three soil horizons at Site 5, however, was lower (pH 4.5 - 4.9) than at the other sites. The only other instance at which the upper horizons approached this degree of acidity was at Site 4, where the pH range was 4.6 to 5.3. If Vaccinium species are acidophilic then the greater soil acidity at Site 5 might be a factor influencing the abundance of Vaccinium at this location.

Another condition which appeared to affect the distribution of the three Vaccinium species was the distance from the surface of the ground water level. At Site 4 which bordered a sphagnum bog these species were distributed relatively uniformly over the area where the ground water level was at a depth of 50 cm. or more. As the depth decreased from 30 cm. to near the surface the number of plants of each species decreased very rapidly.

(c) Characteristics of V. canadense rhizomes and the apparent effects of environmental conditions on their growth and extent

The clonal maps of V. canadense rhizomes from sites 1 to 6 are presented in Figures 1 to 18 in the Appendix. Examination of the maps reveals a high degree of variation in the extent of the rhizomes. The total length of individual rhizomes varied from 66.5 to 1359.0 cm. Even within sites this variability was apparent, for example, at Site 6 the length of rhizomes varied from as little as 97.0 to 1359.0 cm. The data on rhizome depth (Table 9 in the Appendix) show differences which may have been due to site habitat. The rhizomes at all sites were located predominantly in the top 15 cm. of soil. At sites 1, 2, 4 and 6 the range in depth was from the soil surface to 30.0 cm. At Site 3 the rhizomes reached a depth of 17.0 cm. and at Site 5 a depth of 15.0 cm. The depth of the rhizomes at Site 3 may have been related to heavy shade conditions which at this site provided protection from direct sunlight and resulted in increased soil moisture levels. The organic horizons at Site 5, however, are of greater depth than at the other sites. The depth of rhizomes here, therefore, may have been the result of the favourable environmental conditions provided by these horizons. The effects of shade and of organic horizon depth on the depth of rhizomes is illustrated further by comparing the density of the tall tree strata, horizon depth and average rhizome depth at each site (see Table 3).

Table 3. *V. canadense*. A comparison of tall tree density, organic horizon depth[1] and average depth of rhizomes[2] for sites 1 to 6

	Site					
	1	2	3	4	5	6
Density of the tall tree strata	27	12	32	28	5	4
Organic horizon depth	3	6	7	7	10	3
Average depth of the rhizomes	6.8 ± 0.1	8.5 ± 0.9	7.1 ± 0.9	6.9 ± 0.3	4.5 ± 0.9	9.0 ± 2.8

[1] Organic horizon depth expressed in cm.
[2] Average depth of rhizomes expressed in cm.

A comparison of the data from Site 2 with that of Sites 3 and 4 indicates the effects of shade on rhizome depth. Under the relatively open conditions of Site 2 there was an increase in average rhizome depth over that at both Sites 3 and 4. Sites 1 and 6 had similar depths of organic horizons. The relatively heavy shaded conditions of Site 1 were accompanied by a decrease in the average depth of the rhizomes. A comparison of data from Sites 5 and 6 illustrates the effect of organic horizon depth on the average depth of the rhizomes. With the greater depth of the organic horizons at Site 5 the average rhizome depth was less than at Site 6 where under similar shade conditions a decrease in organic horizon depth was accompanied by an increase in rhizome depth. Data presented in Table 10 in the Appendix shows the length of rhizomes for various ranges of diameter for each *V. canadense* clone. Possible effects on radial growth from differing

habitats are not obvious. The rhizomes varied from 0.1 to 1.9 cm. in diameter, the largest proportion of them being 0.3 to 0.4 cm. in diameter.

The numbers of shoots, rhizome growing points, major root locations, dead shoots and decayed rhizome ends were calculated on the basis of 100 cm. of rhizome length for each clone (Table 4). Individual clones differ in these characteristics to a great extent, hence no effects of habitat can be discerned (Table 11 in the Appendix).

Table 4a. V. canadense. Morphological characteristics of rhizomes from sites 1 to 6. Data based upon 100 cm. of rhizome length

	Site					
	1	2	3	4	5	6
No. of shoots	1.2 ± 0.7	1.5 ± 0.6	2.2 ± 0.8	1.9 ± 0.2	1.6 ± 0.6	1.0 ± 0.9
No. of rhizome growing points	0.2 ± 0.2	0.9 ± 0.9	0.2 ± 0.9	0.4 ± 0.6	0.7 ± 0.2	1.2 ± 1.2
No. of major root locations	3.5 ± 1.5	1.3 ± 2.2	1.0 ± 0.5	0.9 ± 0.5	0.6 ± 0.1	1.0 ± 1.2
No. of dead shoots	0.0	0.2 ± 0.3	0.4 ± 0.3	0.4 ± 0.2	0.1 ± 0.1	0.0
No. of decayed rhizome ends	0.5 ± 0.6	0.7 ± 0.5	0.4 ± 0.8	0.4 ± 0.2	0.3 ± 0.2	0.0

The depth of shoot origin, which is the vertical distance of shoot from the soil surface to the point at which it joins the horizontal rhizome, was determined from the rhizome maps for the shoots of each clone at the various sites (Table 12 in the Appendix). No effects of habitat are discernable, the shoots originated predominantly from rhizomes at soil depths of 4 cm. or less but were found to arise from as far as 11 cm. from the surface.

The actual number and percentage of shoots originating at terminal rhizome locations and at mid-rhizome locations is presented in Table 13 in the Appendix. No effects of habitat on shoot position were apparent. The shoots were found to arise most frequently from terminal locations. The average for 18 clones is 72.3% from terminal locations and 27.7% from mid-rhizome locations.

Examination of the V. canadense rhizome maps reveals an important aspect of growth habit common to all clones. The rhizomes characteristically develop numerous lateral branches. The angle of the laterals, at initiation, to the forward part of the original rhizome is invariably less than 90°. This type of structural development is quite reasonable if one considers that rhizomes are in fact underground stems and might be expected to be morphologically similar to above ground stems and branches. With the above ground stems and branches of plants, the angle of lateral branches to the stems in the direction of growth is always less than 90°. If this comparison is valid then by observing the angle of branching of a rhizome one can determine the location of the proximal and distal portions of a clone. The most proximal point of a rhizome would be the location of the original seedling plant. The suggested position of the seedling plant is indicated for each clone mapped.

Several generalizations may be made for the V. canadense rhizomes. Branching of rhizomes is often dichotomous but not consistently so. The current season's growth of a rhizome growing point is characterized by the presence of leaf scales or modified leaves which are absent from older rhizome sections.

The rhizomes of V. canadense were found to have numerous fibrous roots some of them being larger and more important as centers of a clone's absorption system. The larger roots were referred to as major roots and there were often several per clone. These roots ranged in diameter from .01 to .05 cm. The transition from rhizome to root was very rapid at the point of root initiation and was characterized by a marked reduction in diameter of the rhizome to the root. The major roots moved to lower soil depths, branching at frequent intervals. No large or very extensive tap roots were found with any of the clones mapped. All rhizomes had numerous small roots scattered along their entire length; these were reduced in diameter and extent when compared to the major roots. The small roots extended into the surrounding organic and mineral soil horizons.

The oven-dry weight in gms. and the calculated ratio of shoot weight to root plus rhizome weight of each clone of V. canadense from sites 1 to 6 is presented in Table 14 in the Appendix. The data shows a great variation in weight and shoot/root plus rhizome ratios between the clones at each site. The average total oven-dry weight for 18 clones of shoots equals 15.4 gms., of roots plus rhizomes, 55.8 gms., giving an average shoot/root plus rhizome ratio of 0.30.

(d) Characteristics of the rhizomes of V. vitis-idaea var. minus and the apparent effects of environmental conditions on their growth and extent

The clonal maps of V. vitis-idaea var. minus from sites 1 to 5 are presented in Figures 19 to 33 in the Appendix. A large variation in extent of rhizomes is quite apparent upon examination of the maps. The total length of rhizomes varied from 45.5 to 1043.5 cm. As was the case with V. canadense, the length of rhizomes varied greatly within clonal groups at the same sites. Even with the great variation in extent between rhizomes at the same sites, a marked reduction in length is noticeable for all the clones at Site 3. In Table 4 the average total length in cm. of rhizomes and the average number of decayed rhizome ends per site are compared to the data on tall tree density.

Table 4b. V. vitis-idaea var. minus. A comparison of average length in cm. of rhizomes and average number of decayed rhizome ends per site to tall tree density for the sites 1 to 5

	Site				
	1	2	3	4	5
Density of tall tree strata	27	12	32	28	5
Length	320.7 ± 112.4	145.7 ± 63.6	89.5 ± 37.4	584.7 ± 323.2	313.5 ± 122.4
Number of decayed rhizome ends	1.0 ± 0.5	0.9 ± 0.2	3.0 ± 3.6	0.5 ± 0.3	0.3 ± 0.2

The shorter length of the rhizomes at Site 3 is accompanied by an increase in the number of decayed rhizome ends. The rhizomes had decayed at certain points and parts of the clone had become separated. Environmental conditions may have contributed to this occurrence. Possibly the heavy shade conditions which occurred at Site 3 had an influence. The heavy shade could conceivably have reduced clonal vitality while the abundant soil moisture conditions may have contributed to rhizome decay.

Table 15 in the Appendix presents data derived from the maps on rhizome depth. The depth of rhizomes of the clones varied from the surface to 28.0 cm. at Site 1 while the rhizomes of the clones from all other sites reached a depth of 19.0 cm. but were located predominantly at depths of 10 cm. or less. The effect of organic layer on depth of rhizomes is illustrated by comparing the depth of the organic material with the average rhizome depth at each site (Table 5). The greater depth of rhizomes at Site 1 may be related to the extent of the organic layers which are considerably shallower than at the other sites.

Table 5. V. vitis-idaea var. minus. A comparison of the extent of organic layer in cm. and average depth of rhizomes in cm. for sites 1 to 5

	Site				
	1	2	3	4	5
Extent of organic layer	3	6	7	7	10
Depth of rhizomes	10.5 ± 5.4	6.5 ± 0.6	6.3 ± 1.8	3.9 ± 1.6	6.6 ± 0.9

A comparison of Tables 3 and 5 shows that the behaviour of both species with regard to depth of rhizomes was alike where the extent of the organic layer was similar. Data on diameter of each V. vitis-idaea var. minus clone is presented in Table 16 in the Appendix. The diameter of the rhizomes range from 0.05 to 0.5 cm., the largest proportion of them being 0.05 to 0.1 cm. in diameter.

The numbers of shoots, rhizome growing points, major root locations, dead shoots and decayed rhizome ends were calculated for each 100 cm. of rhizome for each clone. Total numbers as well as the number per 100 cm. of rhizome are presented in Table 17 in the Appendix. The variation between clones at each site is considerable and no environmental influences can be discerned. Table 6 shows the average number per 100 cm. of rhizome and the standard deviation of these characteristics for three clones per site.

Table 6. V. vitis-idaea var. minus. Average numbers of various morphological characteristics of rhizomes from sites 1 to 6. The data is based upon 100 cm. of rhizome length

	Site				
	1	2	3	4	5
No. of shoots	2.2 ± 1.2	5.7 ± 4.0	4.1 ± 4.3	3.3 ± 0.3	2.8 ± 0.8
No. of rhizome growing points	1.2 ± 0.5	0.9 ± 1.1	0.0	0.5 ± 0.5	0.5 ± 0.4
No. of major root locations	0.1 ± 0.2	1.3 ± 1.0	1.9 ± 2.0	0.2 ± 0.5	0.0
No. of dead shoots	0.2 ± 0.2	0.7 ± 0.7	0.3 ± 0.3	0.4 ± 0.3	0.5 ± 0.4
No. of decayed rhizome ends	1.0 ± 0.5	0.9 ± 0.2	3.0 ± 3.6	0.5 ± 0.3	0.3 ± 0.2

V. vitis-idaea var. minus clones (Table 17 in the Appendix) and V. canadense clones (Table 11 in the Appendix) differ in the number of shoots per rhizome. The mean number of shoots per 100 cm. of V. vitis-idaea var. minus rhizome is 3.8, more than twice as many as the V. canadense rhizome which is 1.6 per 100 cm. The influence this difference has on the shoot/root plus rhizome ratio is noted on page 27. Data is presented in Table 18 in the Appendix pertaining to the depth of shoot origin of V. vitis-idaea var. minus clones at the various sites. Environment has no apparent effect on the depth at which shoots may originate. It will be seen that shoots can originate from rhizome locations at depths as far as 22.0 cm. from the surface, although the majority arise from locations between 9.0 cm. and the surface. Comparison of data for depth of shoot origin of both V. vitis-idaea var. minus and V. canadense clones shows a difference in this respect. The depth of shoot origin of the former is quite variable whereas with the latter, the depth of V. vitis-idaea var. minus arise mainly from mid-rhizome locations is shown in Table 19 in the Appendix. Differences occur between the clones from Sites 2 and 5 and Sites 1, 3 and 4 which may be related to shade conditions. A comparison of tall tree density and the percentage of shoots at mid-rhizome or terminal rhizome locations (Table 7) illustrates the relationship between shade and shoot location. The number of shoots located terminally increased with an increase in tree density. At the relatively open conditions of Sites 2 and 5 the proportion of shoots at terminal positions is 7.4% and 0.0% respectively. The number terminally located reaches a maximum of 45.0% under the

heavily shaded conditions of Site 3. While the shoots of V. vitis-idaea var. minus were located predominantly at mid-rhizome locations the reverse was true for V. canadense. The percentage of V. vitis-idaea var. minus shoots for 15 clones is 22.1% located terminally and 77.9% located at mid-rhizome locations. With 18 clones of V. canadense the percentage of shoots located terminally is 72.3% and at mid-rhizome locations 27.7%.

Table 7. V. vitis-idaea var. minus. A comparison of tall tree density with the position of shoots on the rhizome. Data on shoot position presented as a percentage

	Site				
	1	2	3	4	5
Density of the tall tree strata	27	12	32	28	5
Shoot position					
Terminal	24.8	7.4	45.0	33.5	0.0
Mid-rhizome	75.2	92.6	55.0	66.5	100.0

The rhizomes of V. vitis-idaea var. minus produce lateral branches in a manner similar to those of V. canadense but not so abundantly. The angle subtended by the laterals is invariably less than 90° which was also noted with respect to V. canadense rhizome laterals. This similarity in the branching of V. vitis-idaea var. minus and V. canadense rhizomes has been compared to the structural development of above ground stems and branches. By observing the angle of branching one can determine the proximal and distal positions

of a rhizome and on this basis locate the position of the original seedling plant. The suggested position of the seedling plant is indicated for each clone mapped. The rhizomes of V. vitis-idaea var. minus and of V. canadense are similar in many respects. The branching of V. vitis-idaea var. minus rhizomes is often dichotomous. The current season's growth of a rhizome growing point is characterized by the presence of leaf scales along their entire length. The rhizome of V. vitis-idaea var. minus is much straighter in growth habit and not subject to the tropisms of the V. canadense rhizome.

The locations of major roots are indicated for each V. vitis-idaea var. minus clone on the maps. These roots varied in diameter from .01 to .03 cm. at their point of origin on the rhizome. The transition from rhizome to root was very rapid. As the roots extended into the surrounding soil they branched frequently and there was a rapid reduction in diameter. None showed the size or growth habit of tap roots. The position of these roots is indicated on the maps to show the loci of the clone absorption systems. All clones in addition had numerous hair-like roots scattered along the entire length of the rhizome.

The oven-dry weight in gms. and the calculated ratio of shoot weight to root plus rhizome weight of the V. vitis-idaea var. minus clones from sites 1 to 5 are presented in Table 20 in the Appendix. The clonal variation at each site is considerable but the consistently lower weight of the clones at Site 3 is noticeable. This substantiates the earlier suggestion that the heavy shade

conditions at Site 3 reduce V. vitis-idaea var. minus clone vitality (page 22). The data show great variation in the ratio of shoot/root plus rhizome between clones but the ratios are consistently much higher than V. canadense clones.

DISCUSSION

1. Clonal Rhizome Studies

Evidence has been presented which indicates the preference of the Vaccinium species for a shaded habitat. V. canadense exhibited the widest adaptability of the species involved while V. vitis-idaea var. minus was found to prefer shaded conditions but was not tolerant of competition from low growing shrubs and herbaceous plants. Shade may have influenced the growth and extent of the rhizomes of both species. With increased shade the depth of V. canadense rhizomes decreased. Under heavily shaded conditions the rhizomes of V. vitis-idaea var. minus were reduced in length and the numbers of decayed rhizome ends increased indicating possible deleterious effects to this species from such conditions. The number of V. vitis-idaea var. minus shoots located terminally as opposed to those located at mid-rhizome positions increased with increased shade.

The depth of the soil organic layer apparently had an influence upon the abundance of V. canadense. An increase in numbers of this species accompanied an increase in the depth of the organic layer. Rhizomes of both V. canadense and V. vitis-idaea var. minus may have been affected by the extent of the organic layer on the soil. A decrease in depth of the rhizomes occurred when the depth of the organic layer increased. Possibly a greater depth of organic layer provides a more favorable medium for the rhizomes allowing them to grow closer to the surface. Similar favorable effects were reported by Trevett (19).

Differences did not exist in soil nutrient levels on the experimental area involved. The pH of the soil did differ between locations. A decrease in soil pH was accompanied by an increase in the numbers of V. canadense. Possible influence of pH on the rhizome growth and extent of either V. canadense or V. vitis-idaea var. minus were not apparent.

The branching of the rhizomes of both V. canadense and V. vitis-idaea var. minus was found to be similar to the branching of above ground stems and branches. If this comparison is valid then the proximal and distal portions of a rhizome may be determined by observation which may have practical importance when propagating these species by rhizome cuttings. Eggert (7) reported that rhizome cuttings of V. angustifolium produced shoots from the distal portions and roots from the proximal ends. His experiments showed that cuttings with the proximal ends treated with rooting hormone produced more roots than those not treated. If the distal ends were treated, the resulting shoot growth was reduced or the cutting did not survive. Under such circumstances the ability to determine the proximal and distal portions of a rhizome by observation would be important.

The shoots of V. vitis-idaea var. minus were found to originate from rhizomes at a greater soil depth than V. canadense. Evidence provided by the present investigation does not support the suggestion by Trevett (19) that shoots originate at a shallow soil depth because of light or an associated stimulus. Shoots of V. canadense were found to originate from depths as far as 11 cm. from the surface and V. vitis-idaea var. minus shoots from as far as 22 cm. Light could

not penetrate to these depths. V. vitis-idaea var. minus clones were found to have approximately twice as many shoots per rhizome when compared to V. canadense. The majority of V. canadense shoots were located terminally on the rhizome whereas the reverse was true for V. vitis-idaea var. minus. The rhizomes of V. canadense were of greater diameter and more subject to tropisms when compared to V. vitis-idaea var. minus rhizomes but both were similar in that branching was often dichotomous and the growing points were characterized by leaf scales. Both species were found to possess major roots as well as an abundance of fine roots which spread through the surrounding organic matter and soil. These species did not possess tap roots as was reported by Hall (9) for V. angustifolium.

LITERATURE REVIEW

2. Plant and Soil Reaction Studies

(a) Plant foliage and soil reaction under natural conditions

It is a known fact that the pH of the cell sap of certain plant species is higher than the isoelectric point of their proteins. With maturation of these species the pH of the cell sap approaches that of the isoelectric point of their respective proteins. Pearsall et al. (14) reported on the isoelectric points of a number of proteins from several species and found that the pH of these were normally on the alkaline side of their isoelectric points. Robertson et al. (15) found the sap and tissue of potato tubers to be acid. However, the acidity was not uniform and tuber parts of older physiological age were more acid. Both Pearsall (14) and Robertson (15) found that a decrease in the normal physiological activity of a plant was accompanied by a change of the pH of the cell sap in the direction of the pH of the isoelectric point of the plant proteins. Kramer and Schrader (13) observed that the acidity of the leaf sap (including the titratable) acidity) of Vaccinium corymbosum was very high compared to that of other plant species. Practically all acidifying substances were readily water-soluble. The pH of the isoelectric point of the water soluble proteins was found to approximate a pH of 5.0. Leaves of younger physiological age were found to have a lower pH than mature leaves. From their results they concluded that in contrast to most plants, the pH of blueberry leaf sap rises towards the pH of the isoelectric point of its proteins upon senescence. They suggested that because the pH of the leaf sap of V. corymbosum is on the acid

side of the isoelectric point of its soluble protein that the proteins being amphoteric in nature were acting as cations. Cain et al. (5) found that healthy leaf tissue had a low pH and a low basic cation content, whereas with chlorotic tissue the reverse was the case.

MATERIALS AND METHODS

2. Plant and Soil Reaction Studies

(a) Plant foliage and soil reaction under natural conditions

Ten locations were chosen at the University Native Fruit Station, Rocky Mountain House, Alberta. Areas fifteen meters square showing relatively uniform conditions of shade, slope and soil moisture were marked with stakes at each location during June, 1956. The variation in elevations between locations were similar to those of (1) Clonal Rhizome Studies (see page 5). A description of each location follows:

A. A north-facing slope of approximately 30° with medium to heavy shade and medium elevation.
B. A south-facing slope of approximately 15° with open conditions and medium elevation.
C. A level area of medium shade conditions and low elevation.
D. A south-facing slope of approximately 10° with medium shade conditions and low elevation.
E. A level area of light to medium shade conditions and low elevation.
F. A level area of very heavy shade conditions and medium elevation.
G. A south west-facing slope of approximately 5° with light shade conditions and low elevation.
H. An east-facing slope of approximately 5° with medium shade conditions and low elevation.

I. An east-facing slope of approximately 10° with medium to heavy shade conditions and medium elevation.

J. A level area of open conditions and high elevation.

Leaf samples weighing approximately 30 gms. of V. canadense, V. caespitosum and V. vitis-idaea var. minus were collected during the summer of 1956 at these locations. V. canadense was present at all locations whereas V. vitis-idaea var. minus was sampled at all locations except G and H. V. caespitosum was found at all locations except A, G and J but leaf samples were collected only at locations D, E and H due to scarcity of this species at the other locations. The leaf samples including all leaves (irrespective of position) from a number of plants were collected on the following dates during 1956: June 22, July 11, August 12, August 29, and September 14. The samples were placed in sealed polyethylene bags and transported to the University at Edmonton. The samples were quick frozen and stored until the late fall of 1956 when they were removed from the freezer and allowed to thaw. Duplicates of each leaf sample were macerated for two minutes in a Waring blender with distilled water, the ratio of leaves to water being 1:10 by volume. The pH determinations of the homogenate were made after a lapse of 30 minutes with a Beckman Zeromatic electrometer.

Leaf samples were collected from the same locations during 1957 on the following dates: June 7, August 2 and September 1, 11, and 26. Additional collections were made during September to determine the pattern of leaf sap pH changes during plant maturation. The collections made on September 26 were at the time of leaf fall in the

case of both V. canadense and V. caespitosum. During 1957, samples of V. caespitosum leaves were collected from all the locations but A, G and J. The samples were handled in the same manner as those collected during the summer of 1956. The pH determinations of leaf homogenates were made during the late fall and winter of 1957. Soil samples were taken from the various locations during August, 1957. Analyses of these samples were made by the Spurway method (18) during the fall of 1958 after being air dried and passed through a 5 mm. sieve.

RESULTS

2. Plant and Soil Reaction Studies

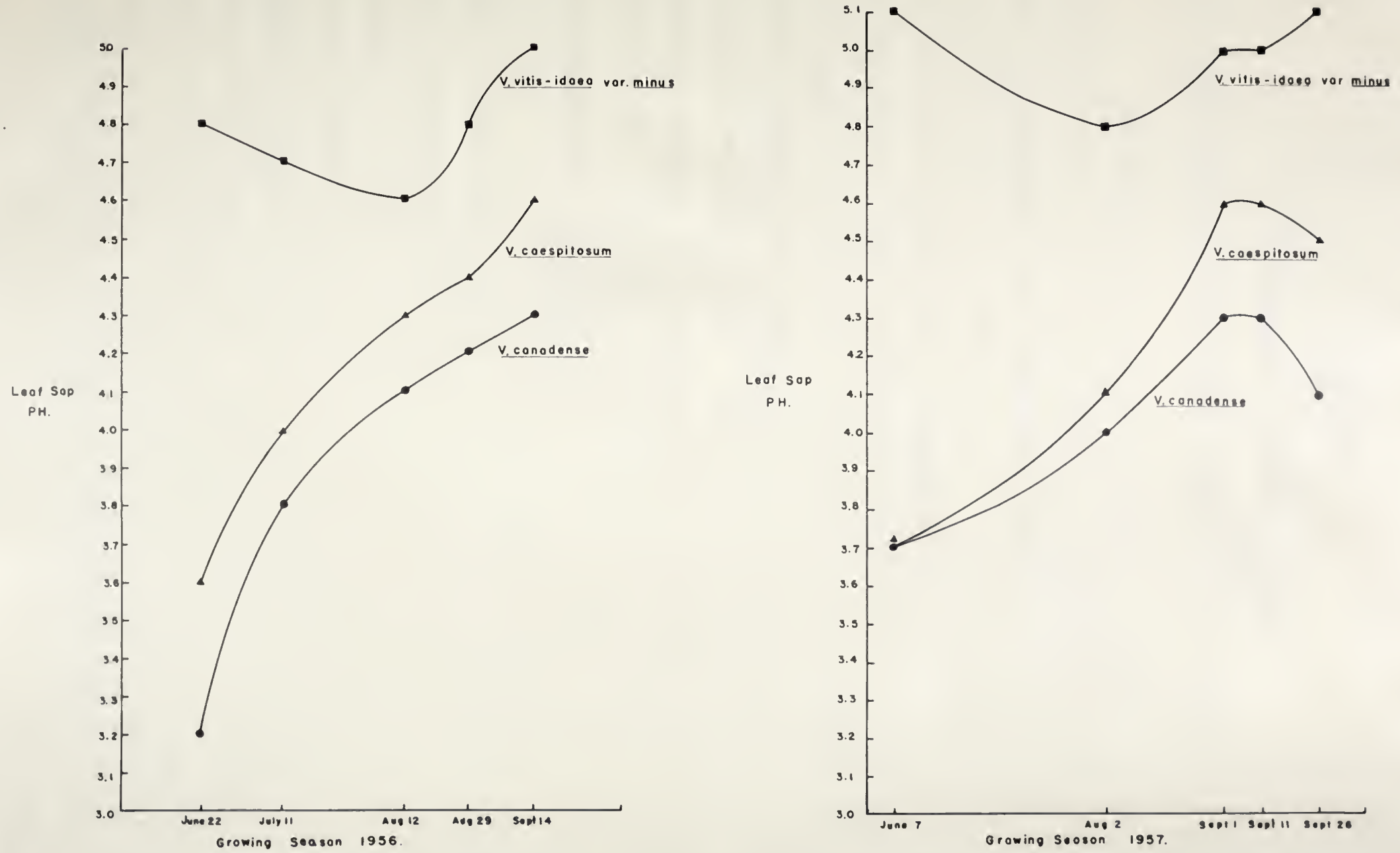
(a) Plant foliage and soil reaction under natural conditions

The pH determinations on leaf sap of the three species, Vaccinium canadense, Vaccinium vitis-idaea var. minus and Vaccinium caespitosum for the 1956 growing season appear in Tables 21, 22 and 23 in the Appendix. The sap pH of each species was consistent irregardless of location, therefore, leaf sap reaction was not influenced to any degree by variation of environmental conditions. Analyses of the soil nutrient, pH and the leaf sap data (see Tables 21, 22, 23 and 27 in the Appendix) shows that there was no correlation between the edaphic conditions and the leaf sap acidity.

Differences in leaf sap pH between the three species were obvious with V. canadense being the most acid, V. vitis-idaea var. minus the least acid while V. caespitosum occupied an intermediate position. Seasonal variations in the pH of leaf sap of each species were also noticeable. The leaf sap of V. canadense showed an increase in pH from 3.2 on June 22 to 4.3 on September 14 (Table 21 in the Appendix) while that of V. caespitosum increased in pH from 3.6 on June 22 to 4.6 on September 14 (Table 23 in the Appendix). The leaf sap pH of V. vitis-idaea var. minus, on the other hand, showed a decrease in pH until August 12 (from 4.8 to 4.6) followed by an increase (4.6 to 5.0) from August 12 to September 14 (Table 22 in the Appendix). pH differences between species as well as seasonal variation of leaf sap pH during 1956 are illustrated in Figure 1.

The pH determinations of leaf sap of the three species, V. canadense, V. vitis-idaea var. minus and V. caespitosum for the 1957 growing season appear in Tables 24, 25 and 26 in the Appendix. Differences in sap pH which existed between species during 1957 were similar to those which occurred during 1956. Although growth resumption was approximately two weeks earlier during 1957, the pattern of seasonal increase in pH was similar to 1956 with V. canadense and V. caespitosum until September 1. After this time a decrease in leaf sap pH was evident with both species. The leaf sap of V. canadense showed a decrease in pH from 4.3 to 4.1 while V. caespitosum leaf sap pH decreased from 4.6 to 4.5 between September 1 and September 26. The leaf sap pH of V. vitis-idaea var. minus showed a very similar seasonal pattern to that of 1956. Once again as in 1956 the leaf sap pH of the three species was apparently not influenced by differing environmental conditions. Differences between species and seasonal variation of leaf sap pH during the 1957 growing season are illustrated in Figure 1.

FIG. 1. The seasonal changes of leaf sap pH of V. canadense, V. caespitosum and V. vitis-idaea var. minus during the growing seasons of 1956 and 1957



Each point represents an average of all the determinations made for each species

DISCUSSION

2. Plant and Soil Reaction Studies

(a) Plant foliage and soil reaction under natural conditions

The results have shown that no apparent correlation existed between the leaf sap pH of V. canadense, V. vitis-idaea var. minus and V. caespitosum and the environmental conditions which were present during the course of the investigation. Leaf sap pH was indicative of the species concerned with V. canadense being the most acid, V. caespitosum occupying an intermediate position while V. vitis-idaea var. minus was the least acid. Seasonal determinations of leaf sap pH of V. canadense and V. caespitosum showed increases with the advance of the growing season. This increase with physiological aging of the leaves is in agreement with the results of Kramer and Schrader (13). During 1957, slight decreases in leaf sap pH of V. canadense and V. caespitosum were evident at the end of the growing season. The leaf sap pH of V. vitis-idaea var. minus did not show the same seasonal pattern of increase as the other two species. The pH decreased during the growing period and increased only slightly at the end of the season. This pattern of change may be related to the pseudo-evergreen nature of this species. V. vitis-idaea var. minus does not follow a regular pattern of leaf fall at the end of each growing season. Under these conditions physiological aging of the leaves would occur over a period of more than one growing season, hence the leaf sap pH would be relatively constant during one season. The physiological changes associated with the seasonal

changes in leaf sap pH of the three Vaccinium species were not investigated during the present study, therefore, no inferences can be made in this regard.

LITERATURE REVIEW

2. Plant and Soil Reaction Studies

(b) The influence of altered soil reaction on *Vaccinium canadense* and *Vaccinium vitis-idaea* var. *minus*

Stene (17) found *Vaccinium corymbosum* tolerated rather wide pH units in the rooting medium, especially when plant nutrients were present in adequate amounts during the growing season. He suggested that a neutral or alkaline growing media interfered with the availability of nutrients and blueberry plants grown in such a medium would have an inadequate supply. Bailey (1) grew *V. corymbosum* in a lime treated soil and found that the lime had an effect which was detrimental to the growth of this species. Acid soil of pH 4.5 was treated with lime at rates of 1,000, 2,000, 4,000 and 8,000 lbs. per acre. These treatments raised the soil pH to 5.0, 5.3, 6.3 and 7.5 respectively. Very low applications of lime (1,000 lbs. per acre) did not raise the soil pH appreciably but reduced plant growth 55 per cent. Addition of peat to the lime treated soil reduced the detrimental effects of lime. Harmer (10) carried out a series of field and greenhouse experiments to investigate the influence of soil pH, sulfur and lime on the growth of the highbush blueberry, *Vaccinium corymbosum* var. *Rubel*. Using acid (pH 3.6) and alkaline (pH 7.6) muck soil and various mixtures of both, a greenhouse experiment was set up to determine the influence of the resulting soil pH on blueberry growth. Total dry weight increased slightly with a decrease in acidity from pH 3.5 to 5.1. With a higher proportion

of alkaline muck and a resultant higher soil pH, the total weight of the plants decreased sharply, especially when the mixture was predominantly alkaline muck. The ratio of top to root was uniform between pH 3.6 to 5.1. With a higher proportion of alkaline muck, root development failed to keep pace with top growth and the ratio increased. During the second year of growth the treatments at pH 5.5 and 5.7 produced the highest number of blossoms and fruits. Soil analysis of the treatments producing poor growth (above pH 5.7) showed a greater amount of calcium, magnesium and nitrate present in the soil. Plants grown under very alkaline soil conditions were dead at the end of the first growing season.

Harmer (10) applied sulfur to alkaline muck soil (pH 7.6) at rates from 2,000 to 16,000 lbs. per acre. Plants grown in the soils of highest sulfur application (pH 4.0) made the best growth. As with the soil mixture trials (see above) the plants in the highest soil pH treatments died after the first season's growth. Field application of sulfur at rates from 500 to 4,000 lbs. per acre to soils of pH 5.8 to 6.2 acidified the soil, the lowest pH of 3.8 to 4.2 resulting from the 4,000 lb. application. Records on yield of fruit for a period of eight years showed correlated increases with increased rate of application of sulfur.

Kramer and Schrader (12) suggested that because V. corymbosum grows on acid soil, low in exchangeable bases, a low cation requirement is necessary for growth under such conditions. Leaf analysis of the Rubel and Pioneer varieties of V. corymbosum by Bailey et al. (2) showed a very low leaf-content of the cations

potassium, calcium and magnesium. Spray and soil applications of magnesium sulfate did not appreciably increase the leaf content of magnesium. Bailey suggested that if the blueberry has a high anion requirement, the anions absorbed must be other than phosphate ions.

The results obtained by Cain (4) with V. corymbosum grown in sand culture indicated that ammonium nitrogen is superior to nitrate nitrogen as a nutrient for blueberries and in fact may be essential. Nitrate nitrogen was even found to be detrimental to the plants. He obtained evidence that ammonium nitrogen was associated in some manner with iron nutrition. This effect was related to the metabolic function of iron, since plants receiving nitrate nitrogen and showing iron deficiency symptoms, contained just as much or more iron in their foliage as those showing no symptoms of deficiency. Cain suggested that one reason for the failure of growth of blueberries on soils of slightly acid, neutral or alkaline reaction might be a deficiency in these soils of ammonium nitrogen. Soils of near neutral reaction are usually favorable for the growth of nitrifying organisms resulting in a high concentration of nitrates. Hence the turn-over of ammonium nitrogen is fast under these conditions. In acid soils, on the other hand, which are favorable for blueberry growth, dinitrifying organisms predominate and nitrate is converted into the ammonium form. Cain also pointed out that soil pH may not necessarily be a direct controlling factor in iron absorption because plants growing on soils of relatively high pH often contained as much iron in their foliage as those growing in soils of low pH. Cain presented data showing a relationship

between blueberry leaf chlorosis on the one hand and the accumulation of the basic cations potassium, calcium and magnesium and an increase in pH of the leaf tissue on the other. He suggested that the pH of the root environment may influence tissue pH and possibly the concentration of basic cations. Green leaves from plants grown in sand culture at pH 7.0 and 4.5 had a tissue pH of 4.1 and 3.3 respectively, but showed no difference in basic cation content. Plants grown in muck soil at pH 3.5 had a basic cation content of 69.2 and were dark green, whereas those grown in soil at pH 6.5 had a basic cation content of 71.2 and were chlorotic. The difference in leaf sap pH was apparently not due to differences in basic cation content and hence may have been the result of increased organic acid production by the plants when grown in acid soil. In such a system then, the leaf sap pH may be determined by the balance between basic cations absorbed and the organic acids produced within the plant. Furthermore, it might be assumed that the cations calcium, magnesium and potassium which constitute the bulk of basic cations absorbed by a plant might be a regulating factor in the function of iron, through their effect on the plant buffer system. Cain suggests that there is a specific low pH optimum for a blueberry enzyme mechanism involving iron which is inactivated by such factors as: a lack of iron, high tissue pH and the presence of certain heavy metals. The inactivation of this enzyme system results in leaf chlorosis. Further work by Cain et al. (5) with chlorotic and healthy leaf tissue of V. corymbosum indicated that the concentration of soluble nitrogenous constituents, such as arginine, were much higher in chlorotic leaves than in green leaves.

Darrow (6) reported on the low temperature dormancy requirements of V. corymbosum and V. ashei plants. He found that V. corymbosum required a minimum of 800 hours at 45° F. or lower whereas V. ashei required only 250 hours.

MATERIALS AND METHODS

2. Plant and Soil Reaction Studies

(b) The influence of altered soil reaction on *Vaccinium canadense* and *Vaccinium vitis-idaea* var. *minus*

Forty *V. canadense* rhizome sections of similar diameter and 15 cm. in length with one above ground shoot per section and 200 *V. vitis-idaea* var. *minus* sections of similar diameter and 15 cm. in length with one shoot per section were taken from the Native Fruit Station at Rocky Mountain House during early May, 1956, and transferred to the University. The sections of *V. canadense* were planted three per 23 cm. pot, using a 2:1 mixture of Native Fruit Station top-soil and Edmonton top-soil. The *V. vitis-idaea* var. *minus* sections were planted five per 23 cm. pot using a similar soil mixture. All plants were plunged into the soil to full pot depth in an area of semi-shade and kept moistened until November 4, 1956. At this time the plants, which had entered a state of winter dormancy, were lifted and placed in controlled temperature storage at a temperature of 34° F.

Preliminary soil amendment trial

Preparatory to adjusting the pH of the soil used for growing the plants, preliminary tests were run on samples of the soil mixture. pH determinations were also run on both the Native Fruit Station soil and the Edmonton soil prior to any mixing. The soils were then mixed and samples taken for pH determinations. All pH determinations were made with a Beckman Zeromatic electrometer. Twenty 1,000 gm.

samples were then taken from the soil mixture and the following treatments applied in duplicate.

1. Control Treatment

No chemicals were added to this soil, however, it was subjected to the same conditions of moistening with distilled water and drying as the other treatments.

2. Calcium Hydroxide Treatments

These treatments involved the addition of calcium hydroxide to amend the soil reaction to an alkaline condition. There were five calcium hydroxide treatments which are outlined in Table 8.

Table 8. Rate of calcium hydroxide application in gms. per 1000 gms. of soil and in lbs. per acre of soil 6 inches in depth

Treatments	$Ca(OH)_2$ per 1000 gms. of soil	$Ca(OH)_2$ per acre
1	0.30	600
2	0.90	1800
3	1.20	2400
4	1.80	3600
5	2.10	4200

The untreated soil was placed in glazed earthenware crocks of 4.5 liter capacity, provided with adequate drainage, and subjected to the following: Each treatment was moistened thoroughly with distilled water and allowed to stand for twenty-four hours.

They were then spread out to air dry. After reaching an air dried condition, the soil was returned to the crocks and moistened thoroughly again. This procedure was repeated six times and pH determinations were made.

3. Sulfuric Acid Treatments

In these treatments sulfuric acid was used to amend the soil reaction to an acid condition. Four lots of soil were placed in 4.5 liter earthenware crocks, with drainage provided, to which 1,250 cc. of sulfuric acid was added per 1,000 gms. of soil. The concentration of acid per treatment is shown in Table 9.

Table 9. Concentration of sulfuric acid application to 1000 gm. soil samples and the equivalent rate of sulfur application in lbs. per acre of soil 6 inches in depth

Treatments	Sulfuric Acid Concentration	Rate of Sulfur Application per acre
1	0.1 N	130
2	0.5 N	650
3	1.0 N	1300
4	10.0 N	13000

The acid was allowed to drain through the soil of the various lots of soil for 24 hours. After draining for this period, 2,000 cc. of distilled water was used to leach the soil. This leaching with distilled water was repeated and the crocks were allowed to drain for another 24 hours. The soil from the various treatments was then spread out to air dry. After reaching an air dried condition, the soil was

returned to the crocks and moistened thoroughly with distilled water. The procedure of moistening and air drying was repeated seven times and the pH was determined on November 26, 1956. The reaction of both acid and alkaline treatments were found to remain relatively constant during the last three periods of leaching and drying. Analysis of all soil treatments for nitrate, ammonium, phosphoric acid, potassium, aluminum, iron, calcium, sulfate and manganese were carried out using the Spurway method (18).

1957 - 1958 altered soil reaction experiment with V. canadense and V. vitis-idaea var. minus

From the results of the preliminary test the rates of sulfuric acid and calcium hydroxide application were selected with which to amend the reaction of the soil to the desired range of pH for preparing the treatments to be used with both V. canadense and V. vitis-idaea var. minus. Five lots of 36.4 kg. of the 2:1 soil mixture were placed in 67.5 liter glazed crocks and the following rates of sulfuric acid and calcium hydroxide applied:

(1) 45 liters of 1.0 N sulfuric acid, an equivalent of 1,300 lbs. of sulfur per acre of soil 6 inches in depth.
(2) 45 liters of 0.1 N sulfuric acid, an equivalent of 130 lbs. of sulfur per acre of soil 6 inches in depth.
(3) No chemicals used.
(4) 425.0 grams of $Ca(OH)_2$, an equivalent of 2,400 lbs. per acre of soil 6 inches in depth.
(5) 850.5 grams of $Ca(OH)_2$, an equivalent of 4,800 lbs. per acre of soil 6 inches in depth.

These soil treatments were made in a manner similar to those of the preliminary trial and were leached and dried six times. Samples from each lot were removed for soil analysis on March 5, 1957.

Plants of V. canadense and V. vitis-idaea var. minus were removed from the cold temperature chambers on February 1, 1957, and March 1, 1957, and placed under greenhouse conditions. Single plants of V. canadense were planted in 2.3 kg. of soil per 23 cm. clay pot. Two plants per soil treatment were prepared at both dates. Five plants of V. vitis-idaea var. minus were planted in 2.3 kg. of soil in a 23 cm. clay pot. Two pots with five plants per pot were prepared for each soil treatment on both dates. Plants of as uniform a size as possible were used. The plants were watered with distilled water at regular intervals throughout their period of growth, using approximately 200 ml. per pot every two days.

Following a season's growth in the greenhouse on November 1, 1957, the potted plants of both V. canadense and V. vitis-idaea var. minus were placed under cold storage conditions at 34° F. to fulfill their winter dormancy requirement. The ten pots (five treatments in duplicate) of each species were placed again under greenhouse conditions on February 1, 1958, and March 1, 1958, and grown on for a second season.

The soil reaction of the various treatments with V. canadense and V. vitis-idaea var. minus were determined during the first year on March 5, 1957, and August 15, 1957. During the second year pH determinations were made on April 2, 1958, and November 1, 1958. Analysis of soil samples from the various treatments with both species were carried

out at the beginning of the experiment during March, 1957, and after its completion during December, 1958. The levels in p.p.m. of available nitrate, ammonium, phosphate, potassium, aluminum, iron, calcium, magnesium and sulfate were determined.

Differences in the growth of each species in response to the soil treatments were noted throughout both the 1957 and 1958 growing seasons and the data recorded. The total linear growth in cm. of the V. canadense plants for each of the various treatments was determined at the end of the first season's growth on October 31, 1957, and at the end of the second season's growth on October 30, 1958. Vernier calipers were used. A count of the actively growing shoots of V. vitis-idaea var. minus per pot was made at the end of the second growing season on October 31, 1958.

At the end of the second growing season on November 2, 1958, all plants were removed from the pots and the soil carefully washed from the roots. Oven-dry weight in gms. of roots, rhizomes and plants were determined for each treatment and each species during November, 1958.

1958 altered soil reaction experiment with V. canadense and V. vitis-idaea var. minus

The experiment carried out in 1957, was repeated with the same two Vaccinium species. Forty, 15 cm. rhizome sections of V. canadense and two hundred, 15 cm. rhizome sections of V. vitis-idaea var. minus having one above ground plant attached were taken from the Native Fruit Station and transferred to the University

during April, 1957. The sections were planted in a 2:1 mixture of Native Fruit Station and Edmonton soil in 23 cm. clay pots and handled in a manner identical to those of 1956. After entering a state of winter dormancy on November 1, 1957, they were placed in a controlled temperature chamber at a temperature of 34° F.

The procedure for amending the soil reaction to the desired range of pH for conducting the 1958 experiment was the same as for the 1957 experiment but with the following adjustments:

Soil lot No. 4. To 36.4 kg. of the 2:1 soil mixture 850.5 gms. of $Ca(OH)_2$ was applied, the equivalent of 4,800 lbs. per acre of soil 6 inches in depth.

Soil lot No. 5. To 36.4 kg. of the 2:1 soil mixture 40 oz. $Ca(OH)_2$ was applied, the equivalent of 6,400 lbs. per acre of soil 6 inches in depth.

The plants of V. canadense and V. vitis-idaea var. minus were removed from the controlled temperature chambers on February 1, 1958, and March 1, 1958, and placed under greenhouse conditions. Single plants of V. canadense were planted in 2.3 kg. of soil per 4.5 liter glazed earthenware crock with proper drainage supplied by small washed gravel. Two crocks, each with a single plant, were prepared for each soil treatment at both dates. Five plants of V. vitis-idaea var. minus were planted in 2.3 kg. of soil per 4.5 liter glazed crock. Two crocks, each with five plants, were prepared for each soil treatment at both dates. The plants of both species were selected for uniformity of size when planted. The plants were watered regularly by applying 200 ml. of distilled water per crock every other day.

The soil reactions of the various treatments were determined on April 2, 1958, and November 1, 1958. Analysis of soil samples from the various treatments were carried out during March, 1958, and December, 1958. The level in p.p.m. of available nitrate, ammonium, phosphate, potassium, aluminum, iron, calcium, magnesium and sulfate were determined at both dates using the Spurway method (18).

Differences in growth response of both species were noted during the growing season and the necessary data recorded. The total linear growth in cm. of the V. canadense plants for the various treatments was determined at the end of the season on October 30, 1958. The active shoots of V. vitis-idaea var. minus were counted on October 31, 1958. The plants of both species were removed from the crocks on November 5, 1958, and the soil carefully washed from the roots. Oven-dry weight in gms. of roots, rhizomes and shoots of both species were determined for each treatment during November, 1958.

RESULTS

2. Plant and Soil Reaction Studies

(b) The influence of altered soil reaction on Vaccinium canadense and Vaccinium vitis-idaea var. minus

Preliminary soil amendment trial

The pH determinations of Native Fruit Station soil, Edmonton black soil and the 2:1 mixture of the two soils is presented in Table 10.

Table 10. A comparison of soil reactions of basic soils and basic soil mixture

Soil	pH
Edmonton black	6.3
Native Fruit Station	5.5
2:1 soil mixture	6.0

Each figure represents an average of duplicate determinations

The soil reaction resulting from the application of the amendments, sulfuric acid and calcium hydroxide followed by leaching and drying, as determined on November 18 and November 26, 1956, are presented by Table 28 in the Appendix. The application of the amendments resulted in a wide variety of soil reactions ranging from the acid side to pH 3.3 and on the alkaline side to pH 7.5 from the control treatment of pH 6.2.

The effects of the addition of these amendments on the nutrient levels and availability of nutrients in the soil is presented in Table 29 in the Appendix. The acid applications increased the amount of sulfate in the soil from nil to 200 p.p.m. with the application of 10.0 N sulfuric acid. The acid leaching removed all the calcium and nitrates which were present in the untreated soil mixture in relatively small amounts. The treatment with acid and the resulting acidification of the soil was apparently unfavorable to the action of nitrate-forming bacteria in producing nitrate. The available aluminum increased to a toxic level in the treatment to which the highest concentration of acid was added, however, no appreciable change in the levels of ammonium, phosphorus, potassium, iron or magnesium occurred. The application of calcium hydroxide affected a correlated increase in the amount of calcium in the soil. Apparently the increased amount of calcium in the soil, even at low levels, is favorable to the action of nitrate-forming bacteria as an increase in soil nitrate occurred even with the lowest application of calcium hydroxide. The amount of ammonium, phosphorus, potassium, aluminum, iron, magnesium or sulfate initially present in the soil did not change upon application of calcium.

1957-58 experiment with V. canadense plants brought under greenhouse conditions on February 1, 1957, and February 1, 1958

The results of soil pH determinations during the growing seasons of 1957 and 1958 of the treatments of V. canadense plants brought under greenhouse conditions February 1, 1957, and February 1, 1958, are presented in Table 11.

Table 11. V. canadense. Seasonal variation in pH of soil treatments with plants grown from February 1, 1957 to November 1, 1958

Treatments	Dates			
	March 5, 1957	August 15, 1957	April 2, 1958	November 1, 1958
1	3.0	3.4	3.5	3.6
2	5.5	5.5	5.6	5.6
3	6.2	6.5	6.5	6.5
4	7.0	7.0	7.1	7.1
5	7.4	7.3	7.4	7.5

Each figure represents an average of determinations of duplicate treatments

All treatments showed fluctuation in pH, the greatest occurring in the most acid treatments. These pH changes might have been the result of leaching away of the chemicals used as amendments. The results of soil analysis carried out at the beginning of the experiment on February 9, 1957, and after its completion on November 1, 1958, are presented in Table 30 in the Appendix. The nitrate content of treatments 4 and 5 were higher than the other treatments for both analyses. The calcium content of the soils of treatments 1 and 2 was considerably less than that of treatment 3. Calcium level of treatments 4 and 5 increased, with increased rates of calcium hydroxide application. Sulfate reached a high level in treatment 1 and showed a decrease with a decrease in application (treatment 2). Analyses showed treatments 3, 4 and 5 had no detectable amount of sulfate present at either date. No appreciable differences existed between

treatments in the levels of phosphorus, potassium, aluminum, iron and magnesium. The nutrients, phosphorus, potassium, iron, calcium and magnesium showed increases with the last date of analyses. Apparently the availability of these nutrients increased during the course of the investigation.

The linear growth in cm. of V. canadense plants grown in the five soil treatments is presented in Table 12. The linear growth was determined at the end of the first growing season on October 31, 1957, and at the end of the second growing season on November 1, 1958.

Table 12. V. canadense. Linear growth in cm. of shoots during the 1957 and 1958 growing seasons

Treatments	Years		Total
	1957	1958	
1	43.5	159.5	203.0
2	62.0	196.0	258.0
3	23.5	130.0	153.5
4	11.5	33.5	45.0
5	3.0	6.5	9.0

Each figure represents the average of duplicate treatments

The plants grown in soil treatment 2 (pH 5.5 - 5.6) made the most linear growth. A decrease in growth occurred with a decrease in pH (treatment 1). With treatments 3, 4 and 5, an increase in pH was accompanied by a correlated decrease in plant growth.

The oven-dry weight in gms. of V. canadense plants grown in the amended soil reaction treatments is presented in Table 13.

Table 13. V. canadense. Oven-dry weight in gms. of roots, rhizomes and shoots grown from February 1, 1957, to November 1, 1958

Treatments	Roots	Rhizomes	Shoots	Total
1	11.0	7.0	5.0	23.0
2	13.5	6.0	9.5	29.0
3	1.5	4.0	3.5	9.0
4	0.5	2.0	1.0	3.5
5	0.5	1.0	0.5	2.0

Each figure represents an average of duplicate treatments

The oven-dry weight of the plants grown in the various treatments showed the same trend of growth response as the data on linear growth. The plants of treatment 2 (pH 5.5 - 5.6) had the highest oven-dry weight followed by plants of treatment 1 (pH 3.0 - 3.6). The plants of treatments 3, 4 and 5 showed correlated decreases in oven-dry weight with increased pH of the soil treatments.

Plants brought under greenhouse conditions on March 1, 1957, and March 1, 1958

The soil pH determinations made during the growing seasons of 1957 and 1958 with V. canadense brought under greenhouse conditions March 1, 1957, and March 1, 1958, are presented in Table 14.

Table 14. V. canadense. Seasonal variation of the pH of soil treatments with plants grown from March 1, 1957, to November 1, 1958

Treatments	Dates			
	March 5, 1957	August 15, 1957	April 2, 1958	November 1, 1958
1	3.0	3.6	3.7	3.7
2	5.5	5.6	5.5	5.5
3	6.2	6.4	6.4	6.6
4	6.9	7.2	7.1	7.0
5	7.4	7.5	7.3	7.4

Each figure represents an average of duplicate treatments

The soil used for these treatments were from the same soil lots used for the experiments started February 1, 1957. The pH of corresponding treatments for both experiments are similar and show the same seasonal changes (Tables 11 and 14). The soil treatments were also very similar in nutrient levels for both experiments for the same reasons. The results of soil analysis, carried out at the beginning of the experiment on March 6, 1957, and after its completion on November 1, 1958, are shown in Table 31 in the Appendix. Comparison of data from Table 30 in the Appendix and Table 31 in the Appendix shows the similarity of nutrient levels of corresponding soil treatments.

The linear growth in cms. of V. canadense plants brought under greenhouse conditions on March 1, 1957, and 1958 and grown in the five treatments of amended soil reaction are presented in Table 15.

Table 15. V. canadense. Linear growth in cms. of shoots during the 1957 and 1958 growing season

Treatments	Years		Total
	1957	1958	
1	151.0	175.5	326.5
2	157.0	287.0	444.0
3	26.0	81.0	107.0
4	8.0	25.0	33.0
5	8.0	7.0	15.0

Each figure represents an average of duplicate treatments

The growth response of the plants was similar to that of the plants from the experiment started on February 1, 1957 (Table 12). The plants grown in treatment 2 (pH 5.5 - 5.6) made the most linear growth followed by plants of treatment 1 (3.0 - 3.7). Amount of linear growth decreased with the increase in pH of soil treatments 3, 4 and 5. A comparison of the total linear growth of plants brought under greenhouse conditions on February 1 (Table 12) to those brought under greenhouse conditions on March 1 (Table 15) shows a greater growth response of the latter which may be related to the dormancy requirement of V. canadense. The V. canadense treatments removed from controlled temperature storage at 34° F. on February 1, 1957, would have had 2,136 hours whereas those removed on March 1, 1957, would have had 2,808 hours at this temperature. Possibly the additional 672 hours at 34° F. received by the V. canadense plants

removed on March 1, 1957, were necessary to fulfill the dormancy requirements of this species, the favorable effect being expressed by increased growth response.

The oven-dry weights in gms. of V. canadense plants grown in the amended soil reaction treatments are presented in Table 16.

Table 16. V. canadense. Oven-dry weight in gms. of roots, rhizomes and shoots. Plants grown from March 1, 1957, to November 1, 1958

Treatments	Roots	Rhizomes	Shoots	Total
1	8.5	5.0	11.5	25.0
2	10.0	7.5	13.0	30.5
3	2.0	4.0	4.5	10.5
4	0.5	2.5	1.0	4.0
5	0.5	1.0	0.5	2.0

Each figure represents an average of duplicate treatments

The oven-dry weight data expressed the same trend in growth response as that of the oven-dry weights of plants removed from cold storage on February 1, 1957. Plants of treatments 1 and 2 had the greatest total weight. The oven-dry weight of the plants grown in treatments 3, 4 and 5 showed a decrease in weight with increased soil pH. The magnitude of the differences in growth response of V. canadense plants grown in the amended soil reaction treatments are shown in Figure 2.

1958 experiment with V. canadense plants brought under greenhouse conditions on February 1, 1958, and March 1, 1958

The experiments started during the spring of 1957 were repeated with plants brought under greenhouse conditions on February 1 and March 1, 1958. The pH determinations of the amended soil treatments used for both dates are presented in Table 32 in the Appendix. A comparison of the pH of the soil treatments used for the experiments initiated in 1957 (Tables 11 and 14) to those of the present experiments (Table 32 in the Appendix) shows a difference in pH between corresponding treatments. Treatment 3 of the 1958 experiments was more acid than the corresponding treatment of 1957 (pH 5.6 compared to 6.5) because the basic soils were of lower pH. The pH of treatments 1 and 2 showed decreases for the same reason. The increase in pH of treatments 4 and 5 was due to an increase in the rate of application of calcium hydroxide to these treatments.

A comparison of the data from Tables 30 and 31 in the Appendix to Tables 34 and 35 in the Appendix shows the similarity of nutrient levels of the amended soils used for the 1958 experiments and the experiments initiated in 1957. Again as was noted with the earlier experiments the soil treatments of high pH (treatments 3, 4 and 5) showed increased levels of nitrate nitrogen whereas sulfate was not detectable. Increases in calcium accompanied increased rate of calcium hydroxide application. With the treatments of low pH (treatments 1 and 2) the level of sulfate increased with increased



1
Range of pH 3.0 to 3.7



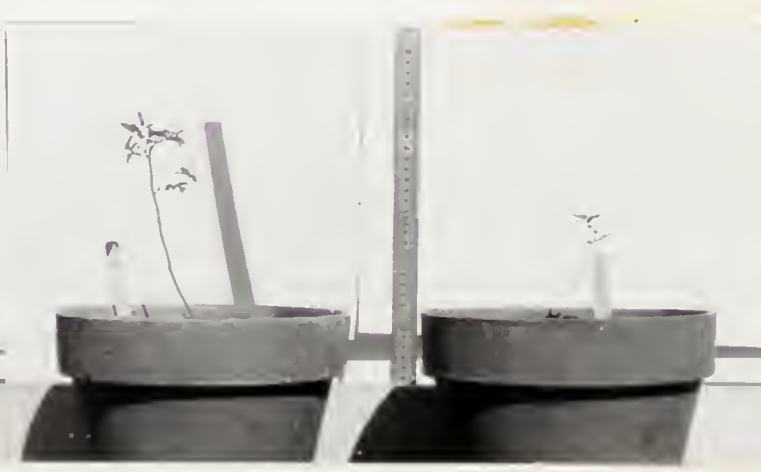
2
Range of pH 5.5 to 5.6



3
Range of pH 6.2 to 6.6



4
Range of pH 6.9 to 7.2



5
Range of pH 7.3 to 7.5

FIG. 2. The growth made by V. canadense plants after 106 days in soils of varied pH under greenhouse conditions

concentration of sulfuric acid application. The nutrients, potassium, calcium and sulfate showed increased availability in the last analyses (November 1, 1958).

The linear growth of V. canadense plants brought under greenhouse conditions on February 1, 1958, and March 1, 1958, and grown in the five treatments of amended soil until November 1, 1958, are presented in Table 33 in the Appendix. Differences in growth response between treatments were similar to those of the experiments initiated during 1957 (Tables 12 and 15). The oven-dry weight in gms. of the V. canadense plants presented in Table 36 in the Appendix also show a similar relationship between treatments in growth response.

1957-58 experiment with V. vitis-idaea var. minus plants brought under greenhouse conditions on February 1, 1957, and February 1, 1958

The results of soil pH determinations of the V. vitis-idaea var. minus treatments during the 1957 and 1958 growing seasons are presented in Table 17.

The soil treatments showed fluctuation in pH, the largest occurring with the most acid treatment. Similar fluctuation in pH of the soil treatments with V. canadense (page 56) was attributed to leaching away of the chemicals used for amendments. The pH of the soil treatments in the experiments with V. vitis-idaea var. minus (Table 17) correspond closely with the pH of the soil treatments with V. canadense (Tables 11 and 14).

Table 17. V. vitis-idaea var. minus. Seasonal variation of the pH of soil treatments with plants grown from February 1, 1957, to November 1, 1958

Treatments	Dates			
	March 5, 1957	August 15, 1957	April 2, 1958	November 1, 1958
1	3.0	3.4	3.7	3.7
2	5.5	5.6	5.6	5.6
3	6.3	6.5	6.4	6.3
4	7.0	7.0	7.1	7.3
5	7.5	7.6	7.6	7.6

Each figure represents an average of duplicate treatments

The results of soil analysis of the treatments carried out at the beginning of the experiment on February 9, 1957, and after its completion on November 1, 1958, are presented in Table 37 in the Appendix. This analysis showed that the relationship between soils in nutrient levels was similar to the nutrient levels of corresponding soils with V. canadense (Tables 30 and 31 in the Appendix). The nitrate nitrogen increased with increase in pH of the soil treatment. The reverse was true for the ammonium nitrogen. Treatments 3, 4 and 5 were high in calcium but sulfate seems to be absent from these soils. Treatments 1 and 2 were low in calcium but sulfate was present in considerable amounts especially in treatment 1. The availability of the nutrients, phosphorus, potassium, calcium, magnesium and sulfate showed increases

during the course of the investigation. No consistent differences in levels of potassium, phosphorus, aluminum, iron and magnesium existed between treatments.

The number of actively growing shoots of V. vitis-idaea var. minus plants brought under greenhouse conditions on February 1, 1957, and February 1, 1958, and grown in the five soil treatments until November 1, 1958, are presented in Table 18.

Table 18. V. vitis-idaea var. minus. Total numbers of actively growing shoots after two growing seasons

Treatment	1	2	3	4	5
Number of stems	249	446	367	145	63

Each figure represents an average of duplicate treatments

The highest numbers of newly developed shoots occurred in treatment 2 (5.5 - 5.6). The growth response of the plants in treatment 3 (pH 6.3 - 6.5) was less than treatment 2 but better than the most acid treatment 1 (pH 3.0 - 3.7). Treatments 4 and 5 (pH 7.0 - 7.3 and 7.5 - 7.6) showed poor growth response, the lowest number of active shoots occurring in treatment 5.

The oven-dry weight in gms. of V. vitis-idaea var. minus plants grown in the amended soil treatments are presented in Table 19.

Table 19. V. vitis-idaea var. minus. Oven-dry weight in gms. of roots, rhizomes and shoots of plants grown from February 1, 1957, to November 1, 1958

Treatment	1	2	3	4	5
Roots	10.0	19.5	13.0	3.0	2.0
Rhizomes	4.0	11.5	10.5	3.0	2.5
Shoots	7.0	25.5	19.0	13.5	4.0
Total	21.0	56.5	42.5	19.5	8.5

Each figure represents an average of duplicate treatments

The oven-dry weight data shows a similar growth response between the plants in the treatments as the data on the numbers of active shoots. Plants from treatment 2 (pH 5.5 - 5.6) yielded the highest oven-dry weight whereas the yields from all the other treatments were lower with a minimum in treatment 5 (pH 7.5 - 7.6).

Plants brought under greenhouse conditions on March 1, 1957, and March 1, 1958

The results of pH determinations of the amended soil treatments with V. vitis-idaea var. minus plants during the 1957 and 1958 growing seasons are presented in Table 20. A comparison of the data from Table 17 and Table 20 shows that the pH of the soil treatments of the experiment started on February 1, correspond closely with the pH of the soil treatments of the present investigation. The soil treatments of both dates also show similar seasonal fluctuation in pH.

Table 20. V. vitis-idaea var. minus. Seasonal variation of the pH of soil treatments with plants grown from March 1, 1957, to November 1, 1958

Treatments	Dates			
	March 5, 1957	August 15, 1957	April 2, 1958	November 1, 1958
1	3.1	3.6	3.6	3.7
2	5.5	5.8	5.7	5.7
3	6.1	6.3	6.4	6.6
4	6.8	7.2	7.2	6.8
5	7.4	7.5	7.4	7.4

Each figure represents an average of duplicate treatments

The results of soil analysis of the treatments carried out at the beginning of the experiment on March 7, 1957, and after its completion on November 1, 1958 (Table 38 in the Appendix) compared to the results of the analyses of the soil from the experiment started on February 1 (Table 37 in the Appendix) shows the similarity of the nutrient levels of corresponding treatments.

The number of actively growing shoots of V. vitis-idaea var. minus plants brought under greenhouse conditions on March 1, 1957, and March 1, 1958, and grown in the five amended soil reaction treatments until November 1, 1958, are presented in Table 21.

Table 21. V. vitis-idaea var. minus. Total number of actively growing shoots after two growing seasons

Treatment	1	2	3	4	5
Number of stems	265	243	183	74	61

Each figure represents an average of duplicate treatments

The greatest number of shoots occurred in treatment 1 (pH 3.1 - 3.7). The growth response of the plants from treatments 1 and 2 (pH 5.5 - 5.7) was similar. The active shoots decreased in numbers with increase in pH in treatments 3, 4 and 5 (pH 6.1 - 7.5). A comparison of data from Table 18 and Table 21 shows that corresponding treatments were not similar in growth response.

The oven-dry weight in gms. of V. vitis-idaea var. minus plants grown in the amended soils are presented in Table 22.

Table 22. V. vitis-idaea var. minus. Oven-dry weight in gms. of roots, rhizomes and shoots of plants grown from March 1, 1957, to November 1, 1958

Treatment	1	2	3	4	5
Roots	14.0	10.0	4.5	1.0	7.5
Rhizomes	5.0	5.0	3.0	2.0	1.5
Shoots	19.5	27.0	16.5	7.0	6.0
Total	39.5	42.0	24.0	10.0	15.0

Each figure represents an average of duplicate treatments

The plants of treatment 1 and 2 showed the highest oven-dry weight, whereas the other treatments yielded lower oven-dry weights with a minimum in treatment 5.

1958 experiment with V. vitis-idaea var. minus plants brought under greenhouse conditions on February 1, 1958, and March 1, 1958

Experiments similar to those initiated during 1957 were repeated during 1958. The results of pH determination of the amended soils used for the 1958 investigation are presented in Table 39 in the Appendix. The pH of the soil treatments of the present investigation differed from the corresponding treatments of the 1957 experiment (Tables 17 and 20). Treatments 2 and 3 were of lower pH whereas treatments 4 and 5 were of higher pH. All treatments showed slight changes in pH by the end of the growing season. Soil analysis data (Tables 40 and 41 in the Appendix) compared to the 1957 data (Tables 37 and 38 in the Appendix) showed that similar nutrient levels existed in the corresponding treatments. Seasonal changes in nutrient availability were also similar.

The number of actively growing shoots of V. vitis-idaea var. minus plants brought under greenhouse conditions on February 1 and March 1, 1958, and grown in the amended soils until November 1, 1958, are presented in Table 42 in the Appendix. Differences in growth response between treatments were similar to those of the 1957 experiments (Tables 18 and 21). The oven-dry weight data of Table 43 in the Appendix also showed a similar relationship to the 1957 treatments in growth response.

DISCUSSION

2. Plant and Soil Reaction Studies

(b) The influence of altered soil reaction on Vaccinium canadense and Vaccinium vitis-idaea var. minus

Both V. canadense and V. vitis-idaea var. minus showed a preference for an acid growing medium of pH 5.5 - 5.6. With V. canadense plants a decrease in the soil pH from 5.5 - 5.6 to 3.0 - 3.6 was accompanied by reduced growth. When compared to the plants grown in the most acid soil treatments (3.0 - 3.6 and 5.5 - 5.6) the plants in the near neutral or alkaline treatments (pH 6.2 - 7.5) showed a marked reduction in growth response. An increase in pH of the latter soil treatments (from 6.2 to 7.5) was accompanied by a correlated decrease in growth of the plants. Harmer (10) reported similar results with V. corymbosum var. Rubel plants grown in soils approximating the same pH as those of the present investigation. Although the V. vitis-idaea var. minus plants made their best growth in soil of pH 5.5 - 5.6 this species appeared to be more tolerant than V. canadense to either an increase or a decrease in soil pH. The plants made satisfactory growth in very acid soil (pH 3.0 - 3.7) and in soil of near neutral reaction (pH 6.1 - 6.6).

The pH of the soil may have had an important influence on the growth of both V. canadense and V. vitis-idaea var. minus, however, the evidence provided by soil analyses indicated that nutrient availability also may have affected the growth of these species. The levels

of available sulfate were high in the soil treatments of lowest pH (3.0 - 3.6 and 5.5 - 5.6) but this nutrient was not detectable in the soil of the other three treatments. The better growth response of V. canadense plants in the former treatments may have been an expression of their need for sulfur. Harmer (10) reported that application of sulfur to soils supporting V. corymbosum var. Rubel resulted in an increase in plant growth and yield of fruit. The possible beneficial effects of sulfur were not apparent with V. vitis-idaea var. minus plants.

The available calcium was increased with the treatments of highest pH (from 6.2 to 7.5). Plants of V. canadense showed poor growth response in these treatments, also a reduction in growth accompanied an increase in available calcium. The plants of V. vitis-idaea var. minus also showed a reduction in growth response with increase in available calcium. Calcium, therefore, may have a deleterious effect on both species. Both Bailey (1) and Harmer (10) suggested that calcium may have had deleterious effects on the growth of V. corymbosum in their respective experiments.

The soil treatments of near neutral or alkaline reaction (pH 6.8 - 7.6) to which calcium hydroxide had been added as an amendment, showed an increase in nitrate nitrogen when compared to the treatments of low pH whereas the reverse was true for ammonium nitrogen. The better growth response of plants of both V. canadense and V. vitis-idaea var. minus grown in the soil treatments that were low in nitrate nitrogen but which showed increased levels of ammonium nitrogen, suggests that ammonium nitrogen is better than nitrate

nitrogen as a nutrient for the two species. Cain (4) obtained similar evidence with V. corymbosum. He found nitrate nitrogen to be detrimental to growth and suggested that ammonium was the blueberry plant's major source of nitrogen.

Perhaps all the factors mentioned (soil pH, levels of available sulfate, calcium, and the form of nitrogen) had an influence on the growth of both V. canadense and V. vitis-idaea var. minus. To determine whether soil pH is the most important condition influencing the growth of these species or whether the indirect effects of soil pH or soil amendment on nutrient availability were more important requires further investigation.

Evidence was presented suggesting that V. canadense plants require approximately 2,808 hours at 34° F. to complete their low temperature winter dormancy period. Plants of V. vitis-idaea var. minus showed satisfactory growth response after 2,136 hours at 34° F. Darrow (6) reported that plants of V. corymbosum only required 800 hours while V. ashei required only 250 hours at 45° F. or lower to fulfill their low temperature dormancy requirements.

LITERATURE REVIEW

3. Shoot and Fruit Growth Studies

Bell (3) working with Vaccinium angustifolium var. laevifolium found this species to have determinate growth resulting from death or inactivation of the growing tip. Rapid shoot growth occurred during the early spring concurrent with blossoming. Cessation of growth occurred at the time of blossom fall. At this time the last formed leaf and the apical meristem withered and died. This withered tip dropped off after a period of ten days. At the time of growth cessation the bud primordium in the leaf axil immediately below the tip developed rapidly into a flower bud. Its development was so rapid that the scar of the dehisced apex was soon crowded to one side and obliterated. The flower bud then occupied the apparent terminal position.

Young (20) studied the fruit growth of three Vaccinium corymbosum varieties and a selection of Vaccinium angustifolium. He found that fruit growth of all the plants concerned followed three distinct stages: (1) rapid increase of the pericarp following fertilization, (2) retarded development of the pericarp coincident with rapid embryo development and (3) a further stage of rapid growth of the pericarp to fruit maturity.

Hindle et al. (11) working with the Vaccinium corymbosum varieties Pioneer, Corville, Pemberton and Dixi found that the growth of the blueberry fruit could be divided into three stages similar to

those described by Young (20). The type of fruiting wood (thin, medium and heavy) did not effect the number of days required for the fruit to mature. The elapsed time from blossom drop to fruit maturity was too variable to be used for prediction of time of harvest. Studies of the influence of sun and shade on the number of days to maturity indicated that fruits which were shaded matured more slowly than those in the sun.

Eggert (7) found that the earliest emerging shoots of Vaccinium angustifolium made the most growth and had an increased capacity for fruiting due to an increase in the number of flower buds. The increase in number of flower buds with the more vegetative shoots suggested an association between vigor of an individual shoot and its ability to develop flower bud primordia.

MATERIALS AND METHODS

3. Shoot and Fruit Growth Studies

Three stems of Vaccinium canadense were selected and marked at each of the six sites used previously in Clonal Rhizome Studies (page 5). This was done on June 8, just previous to the seasonal resumption of growth and flowering. Three stems of Vaccinium vitis-idaea var. minus were selected at the same time at all sites except Site 6. Measurements in cm. of shoot growth and fruit development were made with Vernier calipers on the following dates: June 22, July 10, July 25, August 10, and August 28, 1956. The shoots selected for measurement were those having the highest position on the stems in each case. The fruits measured were the basal ones in the uppermost fruit clusters of the stems. The measurements were discontinued after August 28, 1956, when the plants of both species had formed terminal buds and their fruit had reached full maturity.

The experiment was repeated during 1957 using different stems of the same two species. Stems were selected previous to growth resumption and flowering on May 22. Measurements in cm. of shoot growth and fruit development were made on the following dates: June 6, June 19, July 2, July 15, August 2, August 16, and August 31, 1957.

The recording of data was discontinued after August 31, 1957, a time when the shoots of both species had shown complete cessation of growth by forming terminal buds and the fruit had reached a fully ripened state or had fallen.

RESULTS

3. Shoot and Fruit Growth Studies

(a) Shoot and fruit growth of Vaccinium canadense during the growing seasons of 1956 and 1957

(1) Shoot growth

The data on V. canadense shoot growth for the 1956 growing season are presented in Table 44 in the Appendix. It will be seen from these data that the majority of shoots made their greatest increase in length during the first two weeks of growth between June 8 and June 22. Individual shoots showed quite large increases in length up to July 10. Subsequent growth was slight with only certain shoots showing an increase in length concurrent with terminal bud formation. The majority of shoots* did not show increase in length at this time.

From the data on V. canadense shoot growth for the 1957 growing season (Table 45 in the Appendix) it will be noticed that the seasonal pattern of growth was similar to that of 1956. There was the same rapid growth rate in the early growing season followed by a decrease in growth rate followed by a second noticeable increase in rate of growth with formation of the terminal bud. The end of the

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* The shoots not showing increases in length were those showing die-back and pseudo-abscission of the growing tip concurrent with bud formation. This phenomenon was reported by Bell (3) as an expression of determinate growth of V. angustifolium. The dead portion of the tip persisted for a short time and then dropped off the shoot. The bud which formed laterally just below the tip developed in a manner which made it difficult to distinguish from a true terminal bud. The shoots affected are indicated in Tables 44 and 45 in the Appendix.

first flush of growth coincided approximately with the first increase in size of fruit in V. canadense during both years.

Considerable variation existed in the total growth in length between shoots at each site in both years and at no time was there any indication of an influence of environmental conditions on growth (Table 23).

Table 23. V. canadense. 1957. Mean shoot growth in cm.

Sites	1	2	3	4	5	6
Mean shoot growth	1.3 ± 0.1	1.7 ± 1.4	3.3 ± 1.3	1.9 ± 1.7	1.2 ± 0.8	2.0 ± 0.6

Each measurement represents the mean length of three shoots

Shoot growth was comparable at the sites of maximum shade (Site 3) and maximum exposure (Site 6) whereas the sites of intermediate shade conditions showed reduced shoot growth. Light conditions, therefore, did not have an apparent influence on shoot growth of V. canadense. As in 1956, death and pseudo-abscission of the growing tips of the majority of shoots measured, was again noted (Table 45 in the Appendix).

(2) Fruit growth

Fruit growth measurements of V. canadense taken during the 1956 growing season are presented in Table 46 in the Appendix. These data show that the flowering of V. canadense occurred on or just prior to June 22 at all sites. The fruit increased rapidly in size during the period between blossoming and July 10. A reduction in the rate of increase occurred beginning approximately July 10 and ending approximately

August 10 just prior to the time of fruit ripening. The time of fruit ripening varied considerably between the plants involved. With the start of blue coloration a rapid increase in fruit size occurred until complete coloration at maturity. There was considerable variation between the fruits from the individual stems at the time of initiation and during the period of development, but all followed a similar pattern. A rapid increase in size occurred just after blossom drop; this was followed by a reduced rate of increase, which in turn was followed by a rapid rate of increase to maturity.

Environmental conditions seemed to have an influence on the time to fruit maturity (Table 46 in the Appendix). All the berries from plants at the open exposed conditions of Site 6 were fully ripe on August 10 whereas the majority from the sites of increased shade reached full maturity only by August 28.

The data on fruit growth of V. canadense, measurements made during the 1957 growing season, are presented in Table 47 in the Appendix. During the 1957 growing season the fruit was initiated approximately two weeks earlier than in 1956 (Table 46 in the Appendix) and the same pattern of development took place. Once again there was considerable variation between stems in the time of initiation and the period of fruit growth. Environmental conditions also appeared to have influenced the time to fruit maturity in the same manner as occurred in 1956. All the fruits measured at the relatively exposed sites 5 and 6 were fully mature by August 16 while the fruit from the sites with more tree cover were inconsistent in this respect, the majority being fully mature on August 31.

(b) Shoot and fruit growth of Vaccinium vitis-idaea var. minus during the growing seasons of 1956 and 1957

(1) Shoot growth

The shoots of V. vitis-idaea var. minus made their greatest increase in length during the early growing season (Tables 48 and 49 in the Appendix). In 1956 the majority of them made their most rapid growth between June 8 and June 22. Some slight growth also accompanied terminal bud formation during the latter part of August. A number of shoots (sites 1, 3, 4 and 5) did not increase in length with terminal bud formation. Only two of these shoots exhibited the die-back and pseudo-abscission so common in V. canadense.

During 1956 a possible environmental influence on shoot growth was indicated (Table 24). The mean total linear growth was highest at the locations of moderate to heavy shade (sites 2, 3 and 4).

Table 24. V. vitis-idaea var. minus. 1956. Shoot growth

Sites	1	2	3	4	5
Mean shoot growth	1.6 ± 0.1	2.7 ± 0.2	2.4 ± 0.9	2.6 ± 1.4	1.4 ± 0.1

Each measurement represents the mean length in cms. of three shoots

The time of resumption of growth varied widely between shoots during 1957 (Table 49 in the Appendix). Certain shoots (sites 3 and 4) commenced growth previous to June 6 whereas others (sites 1 and 5) did not do so until as late as June 19. During both years the time of

cessation of rapid shoot growth early in the growing season corresponded approximately with the flowering period of V. vitis-idaea var. minus. Again as in 1956 a number of shoots did not increase in length with terminal bud formation. Die-back and pseudo-abscission was observed with only three shoots. Environmental effects on growth were not obvious.

(2) Fruit growth

The fruit growth of V. vitis-idaea var. minus was not serial as was the case with V. canadense. This is shown in Table 50 in the Appendix and Table 51 in the Appendix. As with V. canadense, however, the rate of growth was rapid just after blossom drop but as the season advanced the rate gradually decreased. The majority of the berries did not show an increase in size with maturation. Possible effects of environment on the growth of the fruit were not detectable in either year.

DISCUSSION

3. Shoot and Fruit Growth Studies

The shoots of both V. canadense and V. vitis-idaea var. minus made their greatest increases in length during the first two weeks of the growing season. Only slight increases in length occurred during the remainder of the season. These latter increases were concurrent with terminal bud formation late in the growing season. Bell (3) reported a similar pattern of seasonal shoot growth for V. angustifolium var. laevifolium, a species which also exhibited the die-back and pseudo-abscission that was shown by V. canadense and to a lesser extent by V. vitis-idaea var. minus during the present investigation. Bell suggested that this occurrence was a manifestation of a determinate growth habit.

The evidence presented suggests that environment has an influence on the shoot growth of V. vitis-idaea var. minus. Linear growth was greatest at the sites of moderate to heavy shade. Similar environmental influences on the shoot growth of V. canadense were not apparent.

Fruit growth of V. canadense was found to follow three stages: a rapid increase in size, followed by a reduced growth rate, which in turn was followed by a rapid rate of increase to maturity. This fruit growth pattern was similar to that reported by Young (20) with V. corymbosum and V. angustifolium and by Hindle et al. (11) with V. corymbosum. The fruit of V. vitis-idaea var. minus did not show a

serial growth pattern. Growth was rapid just after blossom drop but the rate of growth decreased gradually as the season advanced and there was no increase in rate with fruit maturity.

The cessation of rapid shoot growth with V. canadense, early in the growing season, coincided approximately with the initiation of fruit growth. Bell (3) reported a similar occurrence with V. angustifolium var. laevifolium. V. vitis-idaea var. minus differed in this regard in that the cessation of rapid shoot growth coincided approximately with flowering.

LITERATURE REVIEW

4. Vegetative Propagation Studies of *Vaccinium*

Due to economic aspects, investigations concerning *Vaccinium* propagation have in the past been mainly carried out with the commercial highbush blueberry, *V. corymbosum*. References to vegetative studies involving the lowbush blueberry species (including *V. canadense*) and the cranberries (including *V. vitis-idaea* var. *minus*) are few. Eggert (7), however, reported that the lowbush blueberry can be readily propagated using rhizome cuttings. The cuttings were found to exhibit polarity, that is the tip (the end most distant from the seedling plant of a clone) produced the shoots whereas the basal end (the portion proximal to the seedling plant) produced the roots. Rooting hormone applied to the basal ends of the cuttings resulted in increased rooting and shoot growth but when the hormone was applied to the tip end, growth of both roots and shoots was either reduced or the cuttings did not survive.

MATERIALS AND METHODS

4. Vegetative Propagation Studies of *Vaccinium*

Propagation studies involving *V. canadense* and *V. vitis-idaea* var. *minus* were started during June, 1956, at the Native Fruit Station. Two cultivated plot areas were prepared: (a) an area of medium elevation and moderate shade and (b) an area of low elevation, bordering a sphagnum bog and with moderate shade. The elevation of the plots involved were similar to those of the Clonal Rhizome Studies (page 5). Clones of *V. canadense* were lifted from their natural habitat and divided to prepare the following treatments:

(1) Control - rhizome cuttings, 15 cm. in length with an above ground shoot not pruned.
(2) Rhizome cuttings, 15 cm. in length with the above ground shoot moderately pruned (i.e., weak lateral branches were removed and the terminal stem reduced one-quarter in length).
(3) Rhizome cuttings, 15 cm. in length with the above ground shoot removed completely.
(4) Rhizome cuttings, 15 cm. in length taken from mid-rhizome sections having no above ground shoot.

Fifty cuttings were used for each treatment at both locations; being set horizontally at a soil depth of approximately 5 cm., in rows 60 cm. apart. Observations were made at frequent intervals during the growing season of 1956 and data on survival and apparent vigor were recorded.

The study was repeated in 1957 and the experiments were designed to facilitate statistical analyses of the data. Five replicates of each treatment were involved. Seasonal observations were made during the growing season and data recorded on survival and vigor. During September ten rhizome cuttings from all treatments were removed to the laboratory and oven-dry weight in gms. determined on the present season's growth.

V. vitis-idaea var. minus rhizomes were lifted from two locations: (a) from the organic cover of a forested area of high elevation and (b) from sphagnum moss at low elevation. Two propagation techniques were used when preparing these rhizomes for resetting: (1) single rhizome cuttings, approximately 10 cm. in length with one shoot intact and (2) multiple rhizome cuttings which involved groups of cuttings containing ten rhizome sections 10 cm. in length with one shoot per section. These multiple rhizome cuttings were prepared as two types: (a) multiple rhizomes with shoots intact and (b) multiple rhizomes with shoots removed. Twenty-five of the single and twenty-five of each type of multiple cutting from both locations were reset at each of the two cultivated plot locations in rows 60 cm. apart and approximately 15 cm. apart in the rows. Observations on survival and apparent vigor were made at frequent intervals during the 1956 growing season.

During 1957 the study was repeated on an enlarged basis as a factorial experiment involving five replicates. Ten single rhizome cuttings and ten multiple rhizome units of both types from both natural locations for each replicate were lifted from the two cultivated plot areas and removed to the laboratory where oven-dry weight in gms. was determined on the present season's growth during September, 1957.

RESULTS

4. Vegetative Propagation Studies of *Vaccinium*

(a) Propagation experiments with *V. canadense* during 1956 and 1957

Seasonal observations of the 1956 propagation trials revealed that those treatments (3) where shoot pruning was practiced and (4) where cuttings were taken from mid-rhizome sections gave better growth response than the control treatment (1) which involved cuttings with the shoots not pruned. No differences were apparent between identical treatments at the two different plot locations. The investigation carried out during 1957 gave similar results. The survival rate of the rhizome cuttings from the various treatments at both plot areas during 1957 are shown in Table 25.

Table 25. *V. canadense*. The number of surviving rhizome cuttings (25 cuttings per treatment) at two cultivated plot locations

Locations	Treatments			
	1. Control (shoots not pruned)	2. Rhizome cuttings with shoots moderately pruned	3. Rhizome cuttings with shoots removed completely	4. Rhizome cuttings with shoots absent
Medium Elevation	7	11	23	18
Low Elevation	8	13	22	19

L.S.D. for treatments 3.3
Each figure represents the average of five replicates

These results show that the rate of survival in treatments 2, 3 and 4 were better than the control (1) and that in treatment 3 the rate of survival was greater than any of the others. The differences were statistically significant. The analyses of variance (Table 52 in the Appendix) shows that the interaction of location x treatment were not statistically significant, therefore, the location of the cultivated plots had no influence on the response of the cuttings to the various treatments.

The oven-dry weight in gms. of the shoot growth from the rhizome cuttings at both plot areas, during 1957 are shown in Table 26.

Table 26. V. canadense. Oven-dry weight of shoot growth during 1957 at two cultivated plot locations

Locations	Treatments			
	1. Control (shoots not pruned)	2. Rhizome cuttings with shoots moderately pruned	3. Rhizome cuttings with shoots removed completely	4. Rhizome cuttings with shoots absent
Medium Elevation	0.4	0.6	0.8	0.6
Low Elevation	0.5	0.7	0.8	0.7

L.S.D. for treatments 0.2
Each figure represents the average dry weight in gms. of five replicates

While treatments 2, 3 and 4 show more growth than treatment 1 at both locations, only the growth response from treatment 3 could be considered significantly different statistically when compared with that of treatment 1. The analyses of variance (Table 53 in the Appendix)

shows that the interaction of location x treatments were not statistically significant. The growth response of corresponding treatments, therefore, were not influenced by the location of the cultivated plots.

The growth response of the various treatments are shown in Figure 3.

FIG. 3. Shoot regeneration from V. canadense rhizome cuttings prepared as:

1. Control - rhizome cuttings, 15 cm. in length with an above ground shoot not pruned.

2. Rhizome cuttings, 15 cm. in length with the above ground shoot moderately pruned (i.e., weak lateral branches were removed and the terminal stem reduced one quarter in length).

3. Rhizome cuttings, 15 cm. in length with the above ground shoot removed completely.

4. Rhizome cuttings, 15 cm. in length taken from mid-rhizome sections having no above ground shoot.



1



2



3



4

(b) Propagation experiments with V. vitis-idaea var. minus during 1956 and 1957

No apparent differences in growth response occurred with the V. vitis-idaea var. minus rhizome cuttings during 1956 between the two propagation techniques, the two types of multiple rhizome cuttings, rhizomes lifted from different locations or between the two plot locations. Similar results were obtained with the 1957 trials. The average dry weight in gms. of new shoot growth of the rhizomes set out during 1957 are presented in Table 27.

Table 27. V. vitis-idaea var. minus. The effect of propagation technique and pruning on the regeneration of rhizome cuttings removed from two locations and reset at two cultivated plot locations

Cultivated Plot Locations	Rhizome Sources	Propagation Technique		
		Multiple Rhizome		Single Rhizome
		Type of Cutting		
		Shoots Intact	Shoots Removed	Shoots Intact
Medium elevation	Forest conditions of high elevation	0.09	0.07	0.09
	Sphagnum moss at low elevation	0.07	0.09	0.08
Low elevation	Forest conditions of high elevation	0.07	0.07	0.08
	Sphagnum moss at low elevation	0.08	0.07	0.07

Each figure represents the average dry weight in gms. of new shoot growth of one rhizome cutting

It was noted during both years that although the cuttings made new shoot growth, the amount of growth was reduced by some deleterious influence existing at both cultivated plot locations. This apparent influence on growth may have been the result of either of two conditions or both: (1) a lack of the organic layer on the soil of the cultivated plot areas in which the V. vitis-idaea var. minus rhizomes are found, either growing in or just beneath under natural conditions and (2) insufficient shading from tall growing trees at the cultivated plot areas. This species was found by other investigations (page 12) to prefer a shaded habitat.

DISCUSSION

4. Vegetative Propagation Studies of *Vaccinium*

The investigations have shown that *V. canadense* and *V. vitis-idaea* var. *minus* can be propagated using rhizome cuttings. The *V. canadense* cuttings with shoots removed by pruning showed better growth response than the cuttings with the shoots unpruned. The phenomena of rhizome polarity as reported by Eggert (7) was not investigated with either species concerned but observation of rooted rhizome cuttings of *V. canadense* showed indications of polarity by producing shoots and roots at opposite ends. If polarity influences the growth response of rhizome cuttings then the apparent advantage of cuttings with shoots removed over cuttings with shoots absent (shown in Table 25) might be explained on this basis. The growth response of *V. vitis-idaea* var. *minus* rhizome cuttings was apparently not influenced by the propagation techniques used (single or multiple rhizomes) or by shoot removal. Cuttings lifted from differing natural conditions behaved similarly when reset at either of two cultivated plot locations. The reduced amount of new growth of all the cuttings may have been due to environmental conditions of insufficient shade and/or a lack of the organic layer on the soil of the cultivated plots. During the course of the investigations it was noted that while the rhizome cuttings of both species produced new shoot and root growth, the resumption of rhizome growth and spread was altered. Cuttings lifted after three season's growth showed very little rhizome development. An explanation for this phenomenon might be that the rhizome growth of both species was

influenced by the same environmental factors which appeared to reduce the amount of new shoot growth of V. vitis-idaea var. minus (mentioned above).

SUMMARY AND CONCLUSIONS

The preference of the native Vaccinium species for a shaded habitat was established. The growth and extent of the rhizomes of both V. canadense and V. vitis-idaea var. minus may have been influenced by shade, the effect being expressed as a reduction in the rhizome depth of V. canadense and an increase in the number of shoots of V. vitis-idaea var. minus located at terminal rhizome positions. Under heavily shaded conditions the rhizomes of V. vitis-idaea var. minus were reduced in length.

An increase in the depth of the organic layer in the soil was accompanied by an increase in abundance of V. canadense plants. A decrease in the depth of the rhizomes of both V. canadense and V. vitis-idaea var. minus accompanied an increased depth of the organic layer. Possibly the rhizomes of both species find a greater depth of organic layer a more favorable growing medium allowing them to grow closer to the surface.

Possible influences of soil nutrient levels and soil pH on rhizome growth and extent of either V. canadense or V. vitis-idaea var. minus were not apparent.

The evidence presented does not support the suggestion that shoots originate at a shallow depth because of light or an associated stimulus. Shoots of both V. canadense and V. vitis-idaea var. minus originated from rhizomes at depths to which light could not penetrate.

Clones of V. vitis-idaea var. minus were found to have approximately twice as many shoots per rhizome when compared to V. canadense. The majority of V. vitis-idaea var. minus shoots were located at mid-rhizome positions whereas the majority of V. canadense shoots were located at terminal positions.

The rhizomes of both species showed dichotomous branching and the growing points were characterized by leaf scales. V. canadense rhizomes were of greater diameter and more subject to tropisms when compared to those of V. vitis-idaea var. minus.

Both species possessed major roots and an abundance of finer hair-like roots which spread through the surrounding organic matter and soil.

Seasonal changes in leaf sap pH of V. canadense, V. vitis-idaea var. minus and V. caespitosum were also studied. Leaf sap pH, it was noted, increased with physiological aging of the leaves of V. canadense and V. caespitosum. However, the leaf sap pH of V. vitis-idaea var. minus showed a decrease during the early growing season followed by an increase towards the end of the season. The seasonal pattern of change in leaf sap pH of the latter species may have been related to its pseudo-evergreen nature whereby physiological aging would occur over a period of more than one growing season. Leaf sap pH, generally, was indicative of the species with V. canadense being the most acid, V. vitis-idaea var. minus the least, while V. caespitosum occupied an intermediate position. Environmental conditions showed no apparent influence on the leaf sap pH of the three species.

Studies with plants of V. canadense and V. vitis-idaea var. minus grown under greenhouse conditions in soils where the pH was adjusted showed that both species prefered acid soil within the pH range 5.5 - 5.6. V. canadense plants grown in soils of lower pH (3.0 - 3.6) showed reduced growth response. Plants of this species grown in soils of pH 6.2 to 7.5 made less growth than the plants from either of the two most acid soils and an increase in pH was also accompanied by a reduction in growth response. V. vitis-idaea var. minus plants were more tolerant than V. canadense to both decreases or increases in soil pH from the range pH 5.5 - 5.6. Plants of this species made satisfactory growth in the very acid soil (pH 3.0 - 3.7) and in soil of near neutral reaction (pH 6.1 - 6.6).

The pH of the growing medium may have had an important direct influence on the growth of both species but nutrient availability also may have affected the growth of the V. canadense and V. vitis-idaea var. minus plants. Available sulfate reached high levels in the soils of low pH in which V. canadense plants made the best growth, whereas in the soils of near neutral or alkaline reaction sulfate was not detectable and plant growth was reduced. This evidence suggests that sulfur may be an important nutrient for V. canadense. Plants of both V. canadense and V. vitis-idaea var. minus showed reduced growth in the soils high in available calcium. Possibly calcium has a deleterious effect on their growth. The soils of near neutral or alkaline reaction were high in nitrate nitrogen and low in ammonium nitrogen. The reverse was the case with the soils of low pH. The better growth response of both species in soils low in nitrate nitrogen and high in ammonium nitrogen suggests

that the latter may be the better form as a nutrient. Further investigation is required to determine whether soil pH has a direct influence on the growth of V. canadense and V. vitis-idaea var. minus or whether soil pH has an indirect influence on growth due to its influence on nutrient availability.

Plants of V. canadense were found to require approximately 2,808 hours at 34° F. to complete the low temperature winter dormancy period whereas V. vitis-idaea var. minus plants showed satisfactory growth response after 2,136 hours at the same temperature.

The greatest increase in length of shoots of both V. canadense and V. vitis-idaea var. minus occurred during the first two weeks of the growing season. During the course of the investigation concerning shoot growth, the terminal growing point of V. canadense shoots were observed to die-back from the tip. This phenomenon which took place concurrently with bud formation at the end of the growing season was referred to as die-back and pseudo-abscission. It was suggested that this occurrence was a manifestation of a determinite growth habit. Shoots of V. vitis-idaea var. minus were also affected in this manner but to a lesser extent. Environmental influences on the shoot growth of V. canadense were not apparent, however, the shoot growth of V. vitis-idaea var. minus may have been affected by light. Linear growth of the shoots of the latter species was greatest at moderate to heavily shaded sites.

V. canadense fruit growth followed three stages: a rapid increase in size, followed by a reduced growth rate which in turn was followed by a rapid rate of increase to maturity. The fruit of V. vitis-idaea var. minus did not follow this type of serial growth pattern.

Rapid increase in size occurred just after blossom drop but the rate gradually decreased as the season advanced.

The cessation of rapid shoot growth of V. canadense coincided approximately with the time of initiation of fruit growth whereas with V. vitis-idaea var. minus the reduction in rate of shoot growth coincided approximately with the time of flowering.

Vegetative propagation studies with V. canadense and V. vitis-idaea var. minus have shown that both species may be propagated using rhizome cuttings. Severe pruning involving complete removal of shoots of the V. canadense cuttings resulted in improved shoot growth and greater survival of the cuttings when compared to those cuttings with shoots unpruned. Rhizome cuttings taken from mid-rhizome sections having no above ground shoots showed improved survival rate. If the rhizomes of Vaccinium exhibit polarity as was suggested, then the growth response and survival of the rhizome cuttings from mid-rhizome sections with no above ground shoot may have been influenced by the position they were set in the soil. Further investigation of rhizome polarity is required. The determination of the proximal and distal portions of a rhizome by observation as suggested by the Clonal Rhizome Studies may have significance in this regard.

The propagation techniques used (single or multiple rhizome cuttings) and the type of cutting (shoots intact and shoots removed) with V. vitis-idaea var. minus had no apparent influence on the growth response of the rhizome cuttings. Rhizomes lifted from differing natural conditions made similar growth when reset at either of two

cultivated plots. The unsatisfactory growth of all the rhizome cuttings of V. vitis-idaea var. minus may have been related to insufficient shade and/or a lack of an organic layer on the soil of the cultivated plot areas.

During the course of the investigations on propagation with both V. canadense and V. vitis-idaea var. minus, it was noticed that renewed rhizome growth and spread from the rhizome cuttings was altered. Possibly rhizome growth was influenced by the same environmental factors of insufficient shade and/or lack of organic layer which appeared to influence V. vitis-idaea var. minus shoot growth.

LITERATURE CITED

1. Bailey, J. S. The effect of lime applications on the growth of cultivated blueberry plants. Proc. Amer. Soc. Hort. Sci. 38:465-467. 1941.

2. _____, C. T. Smith and R. T. Weatherby. The nutritional status of the cultivated blueberry as revealed by leaf analysis. Proc. Amer. Soc. Hort. Sci. 54:205-208. 1949.

3. Bell, H. P. Determinate growth in the blueberry. Can. Jour. Res. 28:637-644. 1950.

4. Cain, J. C. A comparison of ammonium and nitrate nitrogen for blueberries. Proc. Amer. Soc. Hort. Sci. 59:161-166. 1952.

5. _____ and R. W. Halley. A comparison of chlorotic and green blueberry leaf tissue with respect to free amino acid and basic cation contents. Proc. Amer. Soc. Hort. Sci. 65:49-53. 1955.

6. Darrow, G. M. Rest period requirements for blueberries. Proc. Amer. Soc. Hort. Sci. 41:189-194. 1942.

7. Eggert, F. P. Increasing stand of blueberry plants. Maine Agr. Expt. Stat. Bull. 476:14-15. 1950.

8. _____. Shoot emergence anf flowering habit in the lowbush blueberry. Proc. Amer. Soc. Hort. Sci. 69:288-292. 1957.

9. Hall, I. V. The tap root in the lowbush blueberry. Can. Jour. of Bot. 35:933-936. 1957.

10. Harmer, P. M. Effect of varying the reaction of organic soil on the growth and production of the domesticated blueberry. Soil Sci. Soc. Amer. Proc. 9:133-141. 1945.

11. Hindle, R., V. G. Shutak and E. P. Cristopher. Growth studies of the highbush blueberry fruit. Proc. Amer. Soc. Hort. Sci. 69:282-287. 1957.

12. Kramer, A. and A. L. Schrader. Effect of some nutrients, media, and growth substances on the growth of Cabot blueberry. Jour. Agri. Res. 65:313-328. 1942.

13. _____. Significance of the pH of blueberry leaves. Plant Physiol. 20:93-98. 1945.

14. Pearsall, W. H. and J. Ewing. The isoelectric point of some plant proteins. Biochem. Jour. 18:329-339. 1924.

15. Robertson, I. M. and A. H. Smith. A study of the hydrogen-ion concentration of the potato tuber. Biochem. Jour. 25:763-769. 1931.

16. Stallard, H. Secondary succession in the climax forest formations of northern Minnesota. Ecology. 10:476-547. 1929.

17. Stene, A. Some observations on blueberry nutrition based on greenhouse culture. Proc. Amer. Soc. Hort. Sci. 37:620-622. 1940.

18. Spurway, C. H. and K. Lawton. Soil testing, a practical system of soil fertility diagnosis. Mich. State Agr. Expt. Stat. Tech. Bull. 132. 1949.

19. Trevett, M. F. Observations on the decline and rehabilitation of lowbush blueberry fields. Maine Agr. Expt. Stat. Misc. Bull. 626. 1956.

20. Young, R. S. Growth and development of the blueberry fruit. Proc. Amer. Soc. Hort. Sci. 59:167-172. 1952.

APPENDIX

Table 1. Vegetational analyses of Site 1. Topography - 40° slope facing 26° east of north

Strata	Species	Density	Coverage	Frequency	Dominance	Sociability	Vitality
1. Tall tree*	Pinus contorta	6	2	2			3
	Populus tremuloides	16	3	5	x		3
	Picea engelmanni	3	2	2			3
	Larix laricina	2	1	1			3
2. Shrub*	Shepherdia canadensis	3	1	1			3
	Ledum groenlandicum	4	2	2		Colonies	3
	Alnus crispa	3	2	2			3
3. Low shrub and herbaceous ground level*	Vaccinium canadense	45	2	5	x	Colonies	3
	Vaccinium vitis-idaea var. minus	287	3	5	x	Colonies	3
	Vaccinium caespitosum	12	1	2		Colonies	3
	Amelanchier alnifolia	10	1	2			3
	Solidago decumbens	10	1	2		Colonies	3
	Rosa spp.	5	1	2			3
	Elymus canadensis	50	1	5			3
	Arctostaphylos uva-ursi	50	2	3		Colonies	3
	Pyrola secunda	65	1	5		Colonies	3
	Maianthemum canadense	5	1	2			3
	Fragaria glauca	5	1	1			3
	Epilobium angustifolium	5	1	3			3
	Lathyrus venosus	10	1	3			
	Spiraea alba	5	1	2			3
	Cornus canadensis	5	1	1			3
	Lycopodium clavatum	5	1	1		Colonies	3
	Selaginella spp.					Ground surface mat	
	Hylocomium spp.					Ground surface mat	
	Sphagnum spp.					Ground surface mat	

* Data for the tall tree and shrub stratas represent averages of three 10 sq. meter quadrats
Data for the low shrub and herbaceous ground level strata represent averages of five 1 sq. meter quadrats

Table 2. Vegetational analyses of Site 2. Topography - a 10° slope facing south

Strata	Species	Density	Coverage	Frequency	Dominance	Sociability	Vitality
1. Tall tree*	Populus tremuloides	12	3	5	x		3
2. Shrub*	Shepherdia canadensis	1	1	2			3
3. Low shrub and herbaceous ground level*	Vaccinium canadense	39	2	5	x	Colonies	3
	Vaccinium vitis-idaea var. minus	407	4	5	x	Colonies	3
	Arctostaphylos uva-ursi	120	2	5	x	Colonies	3
	Lathyrus venosus	44	2	5			3
	Elymus canadensis	19	1	4			3
	Fragaria glauca	3	1	2			3
	Spiraea alba	12	1	5			3
	Maianthemum canadense	7	1	3			3
	Amelanchier alnifolia	8	1	3			3
	Galium boreale	7	1	3			3
	Campanula rotundifolia	2	1	2			3
	Rosa acicularus	3	1	2			3
	Anemone multifida	1	1	1			3
	Pyrola secunda	54	2	3		Colonies	3
	Selaginella spp.					Ground surface mat	

* Data for the tall tree and shrub stratus represent averages of three 10 sq. meter quadrats
* Data for the low shrub and herbaceous ground level strata represent averages of five 1 sq. meter quadrats

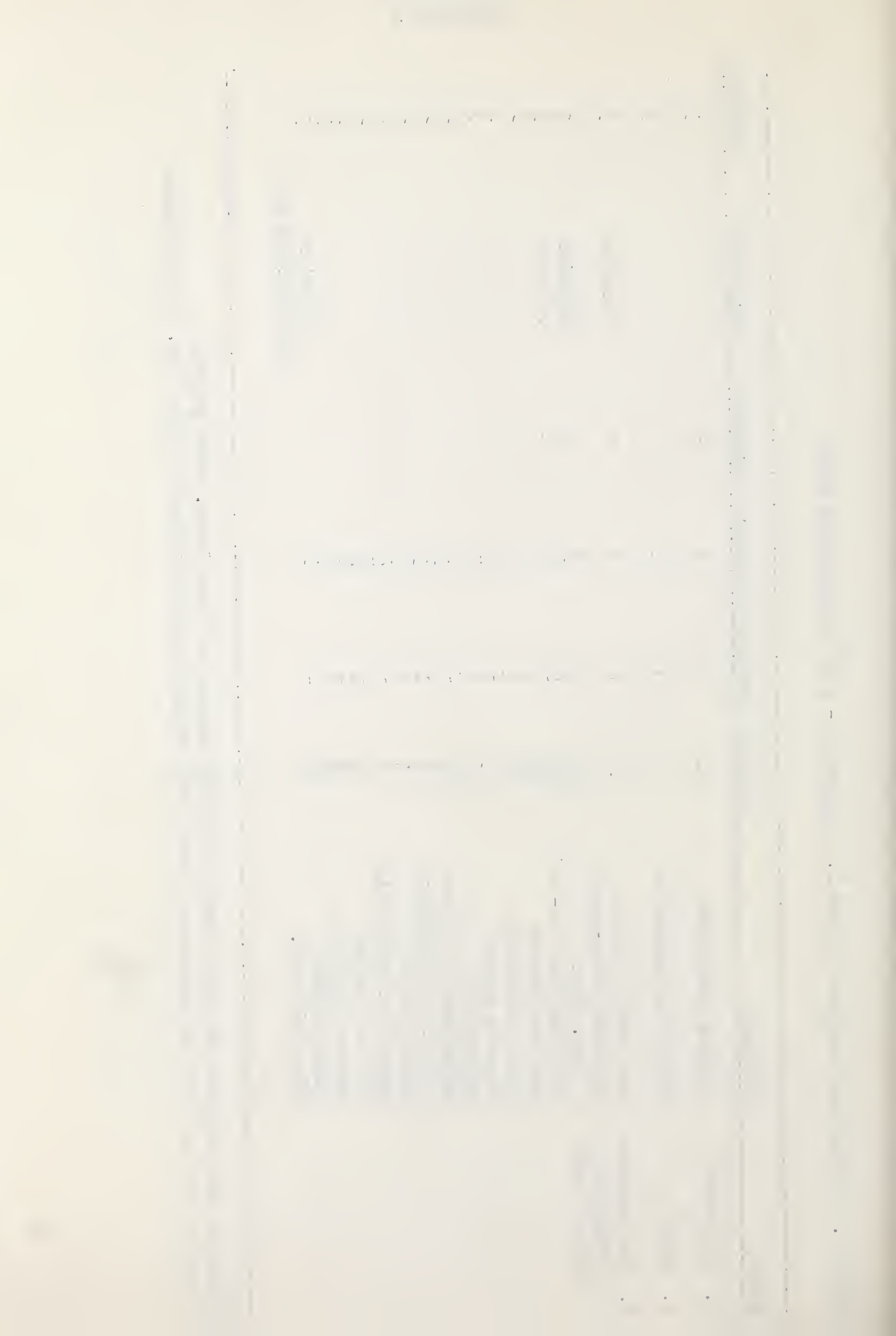


Table 3. Vegetational analyses of Site 3. Topography - a 3° slope facing 56° east of north

Strata	Species	Density	Coverage	Frequency	Dominance	Sociability	Vitality
1. Tall tree*	Populus tremuloides	30	4	5	x		3
	Picea engelmanni	2	2	3			3
2. Shrub*	Salix spp.	16	2	5			3
	Shepherdia canadensis	8	1	3			3
	Ledum groenlandicum	3	1	2			3
3. Low shrub and herbaceous ground level*	Vaccinium canadense	57	3	5	x	Colonies	3
	Vaccinium vitis-idaea var. minus	144	2	5	x	Colonies	3
	Vaccinium caespitosum	45	1	4		Colonies	3
	Maianthemum canadense	18	1	3			3
	Rosa acicularis	12	1	4			3
	Cornus canadensis	13	1	4			3
	Spiraea alba	11	1	4			3
	Epilobium angustifolium	11	2	4			3
	Elymus canadensis	37	1	4			3
	Pyrola secunda	31	1	4			3
	Companula rotundifolia	8	1	2			3
	Lathyrus venosus	14	1	3			3
	Fragaria glauca	1	1	1			3
	Amelanchier alnifolia	6	1	2			3
	Lilium philadelphicum var. andinum	1	1	1			3
	Sphagnum spp.					Ground surface mat	

* Data for the tall tree and shrub stratas represent averages of three 10 sq. meter quadrats
Data for the low shrub and herbaceous strata represent averages of five 1 sq. meter quadrats

Table 4. Vegetational analyses of Site 4. Topography - a 2° slope facing east

Strata	Species	Density	Coverage	Frequency	Dominance	Sociability	Vitality
1. Tall tree*	Populus tremuloides	22	3	5	x		3
	Picea engelmanni	3	2	4	x		3
	Larix laricina	3	2	3			3
2. Shrub*	Shepherdia canadense	2	2	2			3
3. Low shrub and herbaceous ground level*	Vaccinium canadense	63	3	5	x	Colonies	3
	Vaccinium vitis-idaea var. minus	102	2	5	x	Colonies	3
	Vaccinium caespitosum	43	1	5		Colonies	3
	Maianthemum canadense	10	1	4			3
	Rosa acicularis	4	1	2			3
	Cornus canadensis	29	2	5			3
	Spiraea alba	4	1	3			3
	Epilobium angustifolium	2	1	2			3
	Elymus canadense	15	1	4			3
	Pyrola secunda	25	1	5		Colonies	3
	Companula rotundifolia	9	1	2			3
	Lathyrus venosus	8	1	4			3
	Fragaria glauca	14	1	5		Colonies	3
	Amelanchier alnifolia	1	1	1			3
	Galium boreale	8	1	4			3
	Arctostaphylos uva-ursi	13	1	3		Clonal groups	3
	Petasites palmatus	21	2	4			3
	Calamagrostis canadensis	7	1	2			3
	Selaginella spp.					Ground surface mat	
	Sphagnum spp.					Ground surface mat	

* Data for the tall tree and shrub stratas represent averages of three 10 sq. meter quadrats
* Data for the low shrub and herbaceous ground level strata represent averages of five 1 sq. meter quadrats

Table 5. Vegetational analyses of Site 5. Topography - a 3° slope facing 70° east of north

Strata	Species	Density	Coverage	Frequency	Dominance	Sociability	Vitality
1. Tall tree*	Populus tremuloides	4	1	2			3
	Picea engelmanni	1	1	1			3
2. Shrub*	Shepherdia canadensis	1	1	1			3
	Salix spp.	1	1	1			3
3. Low shrub and herbaceous ground level*	Vaccinium canadense	75	3	5	x	Colonies	3
	Vaccinium vitis-idaea var. minus	190	3	5	x	Colonies	3
	Vaccinium caespitosum	36	2	5		Colonies	3
	Maianthemum canadense	4	1	2			3
	Spiraea alba	1	1	1			3
	Rosa acicularis	5	1	2			3
	Epilobium angustifolium	1	1	5			3
	Pyrola secunda	71	1	5		Colonies	3
	Companula rotundifolia	20	1	5			3
	Lathyrus venosa	22	1	5			3
	Fragaria glauca	14	1	5		Colonies	3
	Galium boreale	16	1	5			3
	Arctostaphylos uva-ursi	96	2	5		Colonies	3
	Elymus canadensis	32	1	5			3
	Cornus canadensis	8	1	2			3
	Castillega mineata	6	1	3			3
	Selaginella spp.					Ground surface mat	
	Lichen spp.					Ground surface mat	

* Data for the tall tree and shrub stratas represent averages of three 10 sq. meter quadrats
* Data for the low shrub and herbaceous strata represent averages of five 1 sq. meter quadrats

Table 6. Vegetational analyses of Site 6. Topography - 20° slope facing south

Strata	Species	Density	Coverage	Frequency	Dominance	Sociability	Vitality
1. Tall tree*	Pinus contorta	4	1	2			3
2. Shrub*	Shepherdia canadensis	5	2	2			3
3. Low shrub and herbaceous ground level*	Vaccinium canadense	22	1	5		Clonal groups	2
	Amelanchier alnifolia	11	1	4			3
	Elymus canadense	5	1	2			3
	Arctostaphylos uva-ursi	210	5	5	x	Colonies	3
	Rosa acicularis	2	1	2			3
	Maianthemum canadense	18	1	3			3
	Aster frondeus	10	1	3			3
	Galium boreale	16	1	4			3
	Erigeron drummondi	20	1	3			3
	Lathyrus venosus	11	1	3			3
	Companula rotundifolia	3	1	1			3

* Data for the tall tree and shrubs stratas represent averages of three 10 sq. meter quadrats
* Data for the low shrub and herbaceous strata represent averages of five 1 sq. meter quadrats

APPENDIX I

Table 7. Characteristics of representative soil profiles at sites 1 to 6

Site	Horizon	Depth	Color	Structure and Texture
1	A_{oo}	0 - 3 cm.	black	partially decomposed and undecomposed organic matter
	A_2	3 - 8 cm.	grey to white	platy, fine sand
	B_{21}	8 - 26 cm.	reddish brown	granular sand
	B_{22}	26 - 60 cm.	light reddish brown	granular sand
	C	60 - cm.	grey	granular sand
2	A_{oo}	0 - 5 cm.	black	partially decomposed and undecomposed organic matter
	A_o	5 - 6 cm.	black	decomposed organic matter and sand
	A_2	6 - 9 cm.	pinkish grey	platy fine sand
	B_{21}	9 - 50 cm.	reddish brown	granular sand
	B_{22}	50 - 65 cm.	dark brown	uniform silty sand
	C	65 - cm.	grey	granular sand
3	A_{oo}	0 - 6 cm.	black	partially decomposed and undecomposed organic matter
	A_o	6 - 7 cm.	black	decomposed organic matter
	A_2	7 - 14 cm.	pinkish grey	granular sand
	B_1	14 - 30 cm.	light reddish brown	granular sand
	B_2	30 - 42 cm.	dark reddish brown	uniform sifty sand
	C	42 - cm.	brownish grey	granular sand
4	A_{oo}	0 - 5 cm.	black	partially decomposed and undecomposed organic matter
	A_o	5 - 7 cm.	black	decomposed organic matter and sand
	A_1	7 - 12 cm.	whitish grey	granular sand
	B_2	12 - 20 cm.	reddish brown	loose sand
	C	20 - cm.	light reddish brown	loose sand
5	A_{oo}	0 - 8 cm.	black	partially decomposed and undecomposed organic matter
	A_o	8 - 10 cm.	black	decomposed organic matter and sand
	A_2	10 - 15 cm.	pinkish grey	platy fine sand
	B_{11}	15 - 22 cm.	dark reddish brown	granular sand
	B_{12}	22 - 42 cm.	light brown	loose sand
	B_2	42 - 49 cm.	light reddish brown	uniform silty sand
	C	49 - cm.	grey	granular sand
6	A_{oo}	0 - 3 cm.	black	undecomposed organic matter
	A_1	3 - 6 cm.	brownish grey	granular sand
	B_{21}	6 - 24 cm.	reddish brown	loose sand
	B_{22}	24 - 48 cm.	light reddish brown	loose sand
	C	48 - cm.	brownish grey	loose sand

Table 8. Soil analyses in p.p.m. and pH of composite soil samples from sites 1 to 6

Site	Soil Horizon	NO_3	NH_4	P	K	Al	Fe	Ca	Mg	SO_4	pH
1	A_{oo}	nil	3.0	5.5	30.0	nil	nil	70.0	3.0	nil	6.0
	A_2	nil	2.0	5.0	5.0	nil	nil	trace	trace	nil	5.4
	B_{21}	nil	nil	20.5	trace	nil	nil	nil	1.0	nil	5.6
	B_{22}	nil	nil	4.0	trace	nil	trace	trace	1.0	nil	5.9
	C	nil	nil	1.0	trace	nil	trace	150.0	2.0	nil	8.1
2	A_{oo}	nil	2.0	3.0	30.0	nil	trace	100.0	3.0	nil	5.7
	A_o	nil	trace	4.0	15.0	nil	trace	trace	trace	nil	5.0
	A_2	nil	trace	6.0	5.0	nil	trace	nil	trace	nil	5.2
	B_{21}	nil	trace	20.0	5.0	nil	trace	nil	trace	nil	5.9
	B_{22}	nil	nil	2.0	trace	nil	trace	trace	2.0	nil	6.0
	C	nil	nil	5.0	trace	trace	trace	200.0	2.0	nil	7.4
3	A_{oo}	nil	2.0	6.5	35.0	nil	nil	100.0	3.0	nil	5.7
	A_o	nil	trace	2.0	10.0	trace	trace	trace	1.0	nil	5.0
	A_2	nil	trace	1.0	trace	nil	trace	trace	trace	nil	5.0
	B_1	nil	nil	0.5	trace	nil	trace	nil	trace	nil	5.4
	B_2	nil	nil	1.0	trace	nil	trace	nil	2.0	nil	5.2
	C	nil	nil	0.5	trace	nil	trace	200.0	4.0	nil	8.0
4	A_{oo}	nil	20.0	10.0	40.0	nil	nil	trace	2.0	nil	5.3
	A_o	nil	trace	4.5	8.0	nil	trace	nil	trace	nil	4.8
	A_2	nil	trace	4.0	trace	trace	nil	nil	trace	nil	4.6
	B_2	nil	trace	7.0	trace	nil	nil	trace	1.0	nil	6.4
	C	nil	nil	1.0	trace	nil	trace	trace	trace	nil	7.4
5	A_{oo}	nil	2.0	4.0	20.0	nil	trace	40.0	2.0	nil	4.8
	A_o	nil	2.0	6.0	7.0	nil	nil	nil	trace	nil	4.5
	A_2	nil	trace	5.0	5.0	nil	nil	nil	trace	nil	4.9
	B_{11}	nil	trace	2.5	trace	trace	nil	trace	2.0	nil	6.2
	B_{12}	nil	trace	1.0	5.0	nil	nil	trace	trace	nil	6.3
	B_2	nil	trace	2.0	trace	nil	nil	trace	3.0	nil	6.2
	C	nil	trace	0.5	trace	nil	nil	150.0	3.0	nil	8.0
6	A_{oo}	trace	8.0	3.0	35.0	nil	trace	trace	3.0	nil	5.9
	A_1	nil	2.0	4.5	12.0	nil	nil	trace	2.0	nil	5.6
	B_{21}	nil	trace	9.0	5.0	nil	nil	trace	trace	nil	6.0
	B_{22}	nil	trace	4.5	trace	nil	nil	trace	2.0	nil	6.0
	C	nil	trace	2.0	trace	nil	nil	200.0	2.0	nil	8.2

Data presented are averages of duplicate determinations

Table 9. *V. canadense*. Length of rhizomes in cm. at designated ranges of soil depth in cm.

Site	Clone	0.0-5.0	5.5-10.0	10.5-15.0	15.5-20.0	20.5-25.0	25.5-30.0	Total Length	Av. Depth
1	1	10.5	56.0					66.5	6.7
	2	16.0	120.0	8.0				144.0	7.2
	3	9.0	73.5	66.5	12.0	38.0	21.5	220.5	6.4
	Av.	11.8	83.2	24.8	4.0	12.6	7.2	143.7	6.8
2	1	17.5	31.0	19.5	8.5	1.5		78.0	9.0
	2	295.0	263.0	109.5	55.5	8.0	1.0	732.0	7.2
	3	39.5	62.0	37.5	22.0	6.0		167.0	9.3
	Av.	117.3	118.7	55.5	28.7	5.2	0.3	325.7	8.5
3	1	372.5	380.5	132.0	10.0			895.0	6.3
	2	41.5	52.0	70.0				163.5	8.4
	3	44.0	152.5	12.0				208.5	6.7
	Av.	152.7	195.0	71.3	3.3	0.0	0.0	422.3	7.1
4	1	117.5	106.0	44.0	12.0			279.5	6.6
	2	407.0	653.0	191.0	63.0	23.0	4.0	1341.0	6.7
	3	56.0	153.0	48.0				257.0	7.3
	Av.	193.5	304.0	94.3	25.0	7.7	1.3	625.8	6.9
5	1	602.0	517.5	144.5				1264.0	5.7
	2	375.0	178.0					553.0	4.1
	3	152.0	189.0	48.0				389.0	3.6
	Av.	376.3	294.8	64.2	0.0	0.0	0.0	735.5	4.5
6	1	348.0	477.0	516.0	18.0			1359.0	8.2
	2	11.0	19.0	22.0	44.0	1.0		97.0	12.8
	3	220.0	194.5	64.0	11.5	13.0		502.5	6.1
	Av.	193.0	230.2	200.7	24.5	4.7	0.0	653.1	9.0
Average for 18 clones		174.1	204.3	85.1	14.2	5.0	1.5	484.2	7.1

Table 10. V. canadense. Length of rhizomes in cm. at designated ranges of rhizome diameter in cm.

Site	Clone	0.1-0.2	0.3-0.4	0.5-0.6	0.7-0.8	0.9-1.0	1.1-1.2	1.3-1.4	1.5 or larger	Total Length	Average Diameter
1	1		12.0	37.0	15.5		2.0			66.5	0.6
	2	25.0	30.5	83.0	5.0	1.0				144.0	0.4
	3	130.5	90.0							220.5	0.2
	Av.	51.8	44.2	40.0	6.8	0.3	0.7			143.5	0.4
2	1	27.5	15.0	34.5			1.0			78.0	0.4
	2	151.5	533.0	22.5	22.0			3.0		732.0	0.3
	3	21.0	106.5	39.5						167.0	0.4
	Av.	66.6	218.2	32.2	7.3		0.3	1.0		195.0	0.4
3	1	275.0	364.5	227.5	23.0	4.5	1.0			895.0	0.3
	2	26.0	137.5							163.5	0.3
	3	92.5	104.5			11.5				208.5	0.3
	Av.	131.2	202.2	75.8	7.6	5.3	0.3			422.0	0.3
4	1	68.0	57.5	103.0	34.0	10.0	2.0	1.5	3.5	279.5	0.5
	2	523.0	558.0	231.0	24.5	1.0	1.5	2.0		1341.0	0.3
	3	61.0	130.0	56.0	1.0	9.0				257.0	0.4
	Av.	217.3	248.5	130.0	19.8	6.6	1.2	1.2	1.2	625.5	0.4
5	1	293.0	820.0	98.0	53.0					1264.0	0.3
	2	173.0	380.0							553.0	0.3
	3	228.0	161.0							389.0	0.2
	Av.	231.3	453.7	32.6	17.6					735.5	0.3
6	1	215.0	999.0	132.0	1.0	12.0				1359.0	0.3
	2	55.5	9.0	28.5	4.0					97.0	0.3
	3	97.5	363.0	43.0						503.5	0.3
	Av.	122.7	453.7	67.8	1.7	4.0				653.0	0.3
Average for 18 clones		136.8	270.1	63.7	10.1	2.7	0.4	0.4	0.2	484.2	0.4

Table 11. *V. canadense*. Morphological characteristics of clones

Site	Clone	Total No. of Shoots	No. of Shoots per 100 cm. of Rhizome	Total No. of Rhizome Growing Points	No. of Rhizome Growing Points per 100 cm. of Rhizome	Total No. of Major Root Locations	No. of Major Root Locations per 100 cm. of Rhizome	Total No. of Dead Shoots	No. of Dead Shoots per 100 cm. of Rhizome	Total No. of Decayed Rhizome Ends	No. of Decayed Rhizome Ends per 100 cm. of Rhizome	Length of Rhizome
1	1	1	1.5	0	0.0	4	6.0	0	0.0	0	0.0	66.5
	2	3	2.1	0	0.0	4	2.8	0	0.0	2	1.4	144.0
	3	1	0.4	1	0.4	7	3.2	0	0.0	0	0.0	220.5
	Av.	1.7	1.2	0.3	0.2	5.0	3.5	0.0	0.0	0.7	0.5	143.7
2	1	1	1.3	1	1.3	4	5.1	0	0.0	1	1.3	78.0
	2	13	1.8	4	0.5	6	0.8	1	0.1	5	0.7	732.0
	3	1	0.6	4	2.4	3	1.8	1	0.6	0	0.0	167.0
	Av.	5.0	1.5	3.0	0.9	4.3	1.3	0.7	0.2	2.0	0.7	325.7
3	1	23	2.6	0	0.0	7	0.8	5	0.6	1	0.1	895.0
	2	3	1.8	3	1.8	2	1.2	0	0.0	2	1.2	163.5
	3	2	1.0	0	0.0	4	1.9	1	0.5	3	1.4	208.5
	Av.	9.3	2.2	1.0	0.2	4.3	1.0	2.0	0.4	2.0	0.4	422.3
4	1	5	1.7	4	1.4	5	1.8	2	0.7	2	0.8	279.5
	2	28	2.1	4	0.3	11	0.8	4	0.3	5	0.4	1341.0
	3	4	1.6	0	0.0	2	0.8	1	0.4	1	0.4	257.0
	Av.	12.3	1.9	2.7	0.4	6.0	0.9	2.3	0.4	2.7	0.4	625.8
5	1	19	1.5	8	0.6	7	0.6	1	0.1	7	0.6	1264.0
	2	13	2.3	3	0.5	4	0.7	1	0.2	1	0.2	553.0
	3	3	0.8	4	1.0	2	0.5	1	0.3	1	0.3	389.0
	Av.	11.7	1.6	5.0	0.7	4.3	0.6	1.0	0.1	3.0	0.3	735.5
6	1	9	0.7	18	1.3	13	0.9	1	0.1	1	0.1	1359.0
	2	2	2.0	3	3.1	3	3.1	0	0.0	0	0.0	97.0
	3	8	1.6	4	0.8	3	0.6	0	0.0	0	0.0	503.5
	Av.	6.3	1.0	8.3	1.2	6.3	1.0	0.3	0.03	0.3	0.03	653.1
Average for 18 clones		7.7	1.6	3.4	0.6	5.0	1.4	1.0	0.2	1.8	0.4	484.2

Table 12. V. canadense. Number and position of shoots in relation to their rhizome

Site	Clone	Shoots per Clone	Length of Rhizome in cm.	Number of shoots at designated vertical distances in cm. from rhizome origin							Average Depth
				0.0-1.0	1.5-2.5	3.0-4.0	4.5-5.5	6.0-7.0	7.5-8.5	9.0 or over	
1	1	1	66.5			1					4.0
	2	3	144.0	1	1					1	4.5
	3	1	220.5			1					4.0
	Av.	1.7	143.5	0.3	0.3	0.7	0.0	0.0	0.0	0.3	4.2
2	1	1	78.0	1							0.0
	2	13	732.0	11	1					1	1.5
	3	1	167.0					1			6.0
	Av.	5.0	325.7	4.0	0.3	0.0	0.0	0.3	0.0	0.3	2.5
3	1	23	895.0	12	3	5		3			2.0
	2	3	163.5	3							0.5
	3	2	208.5			1				1	6.0
	Av.	9.3	422.3	5.0	1.0	2.0	0.0	1.0	0.0	0.3	3.0
4	1	5	279.5	2	1	1		1			2.5
	2	28	1341.0	21	1	2		3		1	1.5
	3	4	257.0	3	1						0.5
	Av.	12.3	625.8	8.7	1.0	1.0	0.0	1.3	0.0	0.3	1.5
5	1	19	1264.0	9	6	3			1		2.0
	2	13	553.0	9	2		2				1.5
	3	3	389.0	1		2					2.5
	Av.	11.7	735.5	6.3	2.7	1.7	0.7	0.0	0.3	0.0	2.0
6	1	9	1359.0	5		1	1	2			2.0
	2	2	97.0	1						1	5.0
	3	8	502.5	5	1	1				1	3.0
	Av.	6.3	653.1	3.7	0.3	0.7	0.3	0.7	0.0	0.7	3.0
Average for 18 clones		7.7	484.2								2.5

Table 13. *V. canadense.* Location of shoots on the rhizome

Site	Clone	No. of Shoots	Shoots at Terminal Locations		Shoots at Mid-Rhizome Locations	
			Number	Percent	Number	Percent
1	1	1	1	100.0	0	0.0
	2	3	2	66.6	1	33.4
	3	1	0	0.0	1	100.0
	Av.	1.7	1.0	55.7	0.7	44.3
2	1	1	1	100.0	0	0.0
	2	13	8	61.5	5	38.5
	3	1	0	0.0	1	100.0
	Av.	5.0	3.0	53.8	2.0	46.2
3	1	23	19	82.6	4	17.4
	2	3	2	66.6	1	33.4
	3	2	2	100.0	0	0.0
	Av.	9.3	7.7	82.8	1.6	17.2
4	1	5	4	80.0	1	20.0
	2	28	26	92.9	2	7.1
	3	4	4	100.0	0	0.0
	Av.	12.3	11.3	91.0	1.0	9.0
5	1	19	16	84.2	3	15.8
	2	13	11	84.7	2	15.3
	3	3	2	66.6	1	33.4
	Av.	11.7	9.7	78.6	2.0	21.4
6	1	9	7	77.7	2	22.3
	2	2	1	50.0	1	50.0
	3	8	7	87.5	1	12.5
	Av.	6.3	5.0	71.7	1.3	28.3
Average for 18 clones		7.7	6.3	72.3	1.4	27.7

APPENDIX I

Table 14. *V. canadense.* Oven-dry weight in gms. of clones from sites 1 to 6

Site	Clone	Rhizome and Root	Shoot	Ratio of Shoot/ Root plus Rhizome	Total Weight
1	1	7.8	1.9	0.24	9.7
	2	34.6	3.7	0.10	38.3
	3	6.7	3.5	0.52	10.2
	Av.	16.4	3.0	0.29	19.4
2	1	10.6	2.8	0.26	13.4
	2	95.5	16.0	0.17	111.5
	3	14.0	1.5	0.10	15.5
	Av.	40.0	6.8	0.18	46.8
3	1	130.5	49.5	0.38	180.0
	2	16.2	7.0	0.43	23.2
	3	27.1	7.2	0.27	34.3
	Av.	57.9	21.2	0.36	79.1
4	1	78.0	26.1	0.33	104.1
	2	167.5	41.0	0.24	208.5
	3	41.5	10.0	0.24	51.5
	Av.	95.7	25.7	0.27	121.4
5	1	130.4	43.6	0.33	174.0
	2	47.0	24.3	0.52	71.3
	3	26.3	12.3	0.47	38.6
	Av.	67.9	26.7	0.44	94.6
6	1	106.2	15.9	0.15	122.1
	2	5.4	2.3	0.43	7.7
	3	60.1	9.3	0.14	69.4
	Av.	57.2	9.2	0.24	66.4
Average for 18 clones		55.8	15.4	0.30	71.2

Table 15. *V. vitis-idaea* var. *minus*. Length of rhizomes in cm. at designated ranges of soil depth in cm.

Site	Clone	0.0-5.0	5.5-10.0	10.5-15.0	15.5-20.0	20.5-25.0	25.5-30.0	Total Length	Av. Depth
1	1	0.0	81.0	104.0	97.0	65.0		347.0	14.6
	2	222.0	141.0	15.5				378.5	2.9
	3	24.5	58.0	61.0	36.0	35.0	22.0	236.5	13.9
	Av.	82.2	93.3	60.2	44.3	33.3	7.3	320.7	10.5
2	1	56.0	55.0	11.5				122.5	5.7
	2	16.5	53.5	12.0				82.0	7.2
	3	79.0	111.0	42.5				232.5	6.7
	Av.	50.5	73.2	22.0				145.7	6.5
3	1	24.5	82.5	30.0				137.0	7.7
	2	4.0	81.0	2.0				87.0	7.4
	3	34.0	11.5					45.5	3.8
	Av.	20.8	58.3	10.7				89.5	6.3
4	1	226.0	115.5	34.5	28.5			414.5	6.2
	2	296.0						296.0	2.5
	3	941.0	102.5					1043.5	3.0
	Av.	487.6	72.7	11.5	9.5			584.7	3.9
5	1	61.5	36.0	58.5	4.5			160.5	7.6
	2	149.0	246.0	65.0				460.0	6.6
	3	157.5	147.5	15.0				320.0	5.5
	Av.	122.7	143.2	46.2	1.5			313.5	6.6
Average for 15 clones		152.8	88.7	30.1	11.1	6.7	1.5	290.8	6.8

Table 16. *V. vitis-idaea* var. *minus*. Length of rhizomes in cm. at designated ranges of rhizome diameter in cm.

Site	Clone	0.05-0.1	0.2-0.3	0.4-0.5	Total Length	Average Diameter
1	1	167.0	180.0		347.0	0.1
	2	39.0	339.5		378.5	0.3
	3	9.0	227.5		236.5	0.2
	Av.	71.7	249.0		320.7	0.2
2	1		122.5		122.5	0.2
	2	23.0	59.0		82.0	0.2
	3	72.0	131.5	29.0	232.5	0.2
	Av.	31.7	104.3	9.7	145.7	0.2
3	1	137.0			137.0	0.1
	2	30.0	57.0		87.0	0.2
	3	23.0	22.5		45.5	0.2
	Av.	63.3	26.5		89.5	0.2
4	1	337.0	77.5		414.5	0.1
	2	296.0			296.0	0.1
	3	939.0	104.5		1043.5	0.1
	Av.	524.0	60.7		584.7	0.1
5	1	38.5	122.0		160.5	0.2
	2	460.0			460.0	0.1
	3	320.0			320.0	0.1
	Av.	272.7	40.7		313.5	0.1
Average for 15 clones		192.7	96.2	1.9	290.8	0.2

Table 17. *V. vitis-idaea* var. *minus*. Morphological characteristics of clones

Site	Clone	Total No. of Shoots	No. of Shoots per 100 cm. of Rhizome	Total No. of Rhizome Growing Points	No. of Rhizome Growing Points per 100 cm. of Rhizome	Total No. of Major Root Locations	No. of Major Root Locations per 100 cm. of Rhizome	Total No. of Dead Shoots	No. of Dead Shoots per 100 cm. of Rhizome	Total No. of Decayed Rhizome Ends	No. of Decayed Rhizome Ends per 100 cm. of Rhizome	Length of Rhizome
1	1	2	0.6	6	1.7	0	0.0	0	0.0	5	1.4	347.0
	2	13	3.4	5	1.3	0	0.0	1	0.3	1	0.3	378.5
	3	6	2.5	1	0.4	1	0.4	1	0.4	3	1.3	236.5
	Av.	7.0	2.2	4.0	1.2	0.3	0.1	0.7	0.2	3.0	1.0	320.7
2	1	14	11.4	2	1.6	3	2.4	2	1.6	1	0.8	122.5
	2	2	2.4	2	2.4	2	2.4	0	0.0	1	1.2	82.0
	3	9	3.9	0	0.0	1	0.4	1	0.4	2	0.8	232.5
	Av.	8.3	5.7	1.3	0.9	2.0	1.3	1.0	0.7	1.3	0.9	145.7
3	1	2	1.5	0	0.0	1	0.7	1	0.7	1	0.7	137.0
	2	4	4.6	0	0.0	4	4.6	0	0.0	3	3.4	87.0
	3	5	11.0	0	0.0	0	0.0	0	0.0	4	8.8	45.5
	Av.	3.7	4.1	0.0	0.0	1.7	1.9	0.3	0.3	2.7	3.0	89.5
4	1	14	2.9	5	1.2	1	0.2	1	0.2	4	1.0	404.5
	2	9	3.0	2	0.7	3	1.0	0	0.0	0	0.0	296.0
	3	35	3.4	2	0.02	0	0.0	6	0.6	5	0.5	1043.5
	Av.	19.3	3.3	3.0	0.5	1.3	0.2	2.3	0.4	3.0	0.5	584.7
5	1	3	1.9	0	0.0	1	0.6	0	0.0	1	0.6	160.5
	2	17	3.7	2	0.4	1	0.2	4	0.8	1	0.2	460.0
	3	7	2.2	3	0.9	0	0.0	1	0.3	1	0.3	320.0
	Av.	9.0	2.8	1.7	0.5	0.7	0.02	1.7	0.5	1.0	0.3	313.5
Average for 15 clones		9.4	3.8	2.0	0.6	1.2	0.7	1.2	0.4	2.2	1.2	290.8

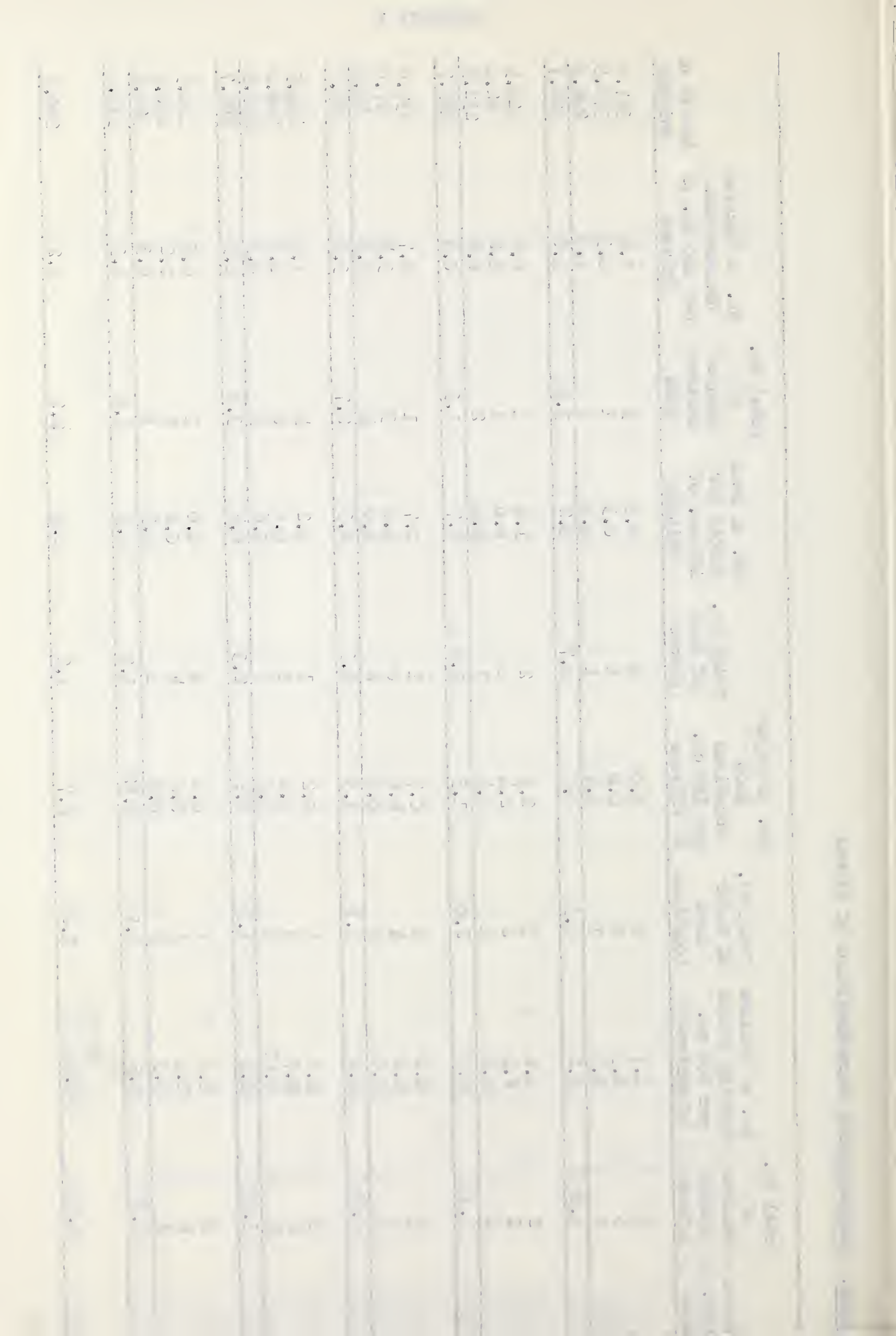


Table 18. *V. vitis-idaea* var. *minus*. Number and position of shoots in relation to the rhizome

Site	Clone	Shoots per Clone	Length of Rhizome in cm.	Number of shoots at designated vertical distances in cm. from rhizome origin							Average Depth
				0.0-1.0	1.5-2.5	3.0-4.0	4.5-5.5	6.0-7.0	7.5-8.5	9.0 or over	
1	1	2	347.0							2	11.0
	2	13	378.5	1			6	4	2		5.5
	3	6	236.5	1	1		2			2	9.0
	Av.	7.0	320.7	0.7	0.3	0.0	2.7	1.3	0.7	1.3	8.5
2	1	14	122.5			10	4				4.5
	2	2	82.0					1		1	7.5
	3	9	232.5	2	1	4		1	1		3.0
	Av.	8.3	145.7	0.7	0.3	4.7	1.3	0.7	0.3	0.3	5.0
3	1	2	137.0							2	11.0
	2	4	87.0			1			1	2	7.5
	3	5	45.5	2		2		1			2.5
	Av.	3.7	89.5	0.7	0.0	1.0	0.0	0.3	0.3	1.3	7.0
4	1	14	404.5	5	2	4	1	1		1	3.0
	2	9	296.0	2	4	3					2.0
	3	35	1043.5	13	10	11		1			2.0
	Av.	19.3	584.7	6.7	5.3	6.0	0.3	0.7	0.0	0.3	2.3
5	1	3	160.5				3				5.0
	2	17	460.0	0	0	7	2	4		4	5.5
	3	7	320.0	1	1	2	1		1	1	4.5
	Av.	9.0	313.5	0.3	0.3	3.0	2.0	1.3	0.3	1.7	5.0
Average for 15 clones		9.4	290.8	1.8	1.2	2.9	1.3	0.9	0.3	1.0	5.6

Table 19. *V. vitis-idaea* var. *minus*. Location of shoots on the rhizome

Site	Clone	No. of Plants	No. of Shoots at Terminal Locations		No. of Shoots at Mid-Rhizome Locations	
			Number	Percent	Number	Percent
1	1	2	1	50.0	1	50.0
	2	13	1	7.7	12	92.3
	3	6	1	16.6	5	83.4
	Av.	7.0	1.0	24.8	6.0	75.2
2	1	14	0	0.0	14	100.0
	2	2	0	0.0	2	100.0
	3	9	2	22.2	7	77.8
	Av.	8.3	0.7	7.4	7.6	92.6
3	1	2	1	50.0	1	50.0
	2	4	1	25.0	3	75.0
	3	5	3	60.0	2	40.0
	Av.	3.7	1.7	45.0	2.0	55.0
4	1	14	5	35.7	9	64.3
	2	9	3	33.3	6	66.6
	3	35	11	31.4	24	68.6
	Av.	19.3	6.3	33.5	13.0	66.5
5	1	3	0	0.0	3	100.0
	2	17	0	0.0	17	100.0
	3	7	0	0.0	7	100.0
	Av.	9.0	0.0	0.0	9.0	100.0
Average for 15 clones		9.5	1.9	22.1	7.6	77.9

Table 20. *V. vitis-idaea* var. *minus*. Oven-dry weight in gms. of clones from sites 1 to 6

Site	Clone	Rhizome and Root	Shoot	Ratio of Shoot/ Root plus Rhizome	Total Weight
1	1	3.1	1.1	0.35	4.2
	2	3.4	2.5	0.74	5.9
	3	2.9	1.8	0.62	4.7
	Av.	3.1	1.8	0.57	4.9
2	1	2.0	1.4	0.70	3.4
	2	1.3	1.6	1.23	2.9
	3	5.3	3.7	0.70	9.0
	Av.	2.9	2.2	0.88	5.1
3	1	1.0	0.6	0.60	1.6
	2	1.5	0.8	0.53	2.3
	3	0.5	0.6	1.20	1.1
	Av.	1.0	0.7	0.78	1.7
4	1	4.3	2.2	0.51	6.5
	2	2.5	1.8	0.72	4.3
	3	22.0	21.3	0.97	43.3
	Av.	9.9	8.4	0.73	18.3
5	1	4.3	4.2	0.98	8.5
	2	6.3	2.3	0.37	8.6
	3	3.6	0.5	0.14	4.1
	Av.	4.7	2.3	0.50	7.7
Average for 15 clones		4.3	3.2	0.69	7.5

FIG. 1

RHIZOME MAP *V. canadense*

Site 1 Clone 1

Scale 1:2, — = 5cm. N

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant



FIG. 2

RHIZOME MAP *V.canadense*

Site 1 Clone 2

Scale 1:2, ▬▬ = 5cm. N

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

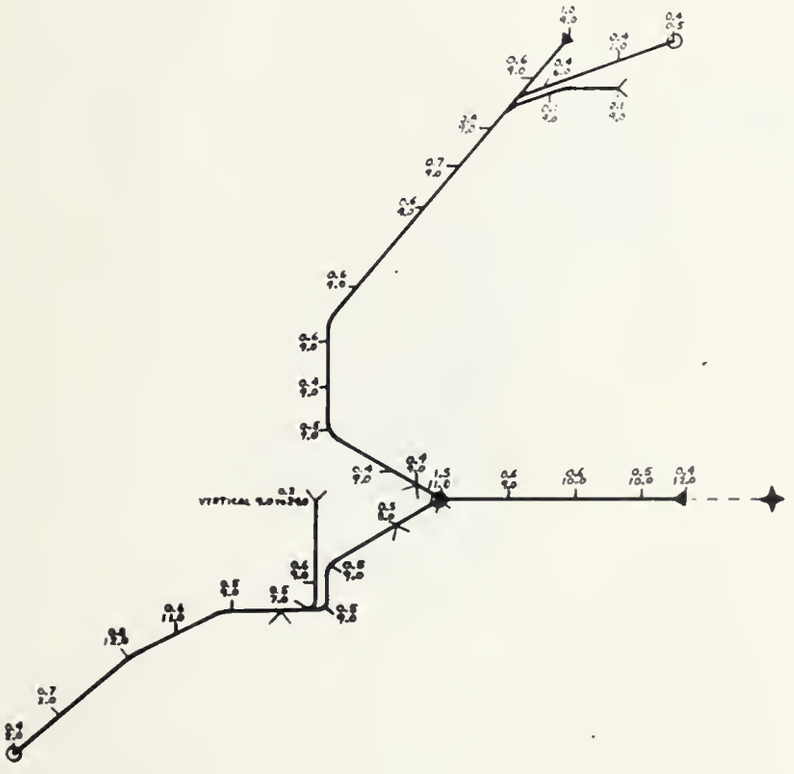


FIG. 3 **RHIZOME MAP *V.canadense***

Site 1 Clone 3

Scale 1:2, ▬▬ = 5cm. N

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
locatian of major roots
rhizome, lower depth at crossing
suggested location of seedling plant



FIG. 4 **RHIZOME MAP *V. canadense***

Site 2 Clone 1

Scale 1:2, ▬▬ = 5cm. N

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

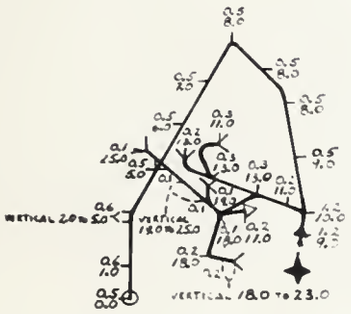


FIG. 5 **RHIZOME MAP *V.canadense***

Site 2 **Clone 2**

Scale 1:2, ▬ = 5cm.

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

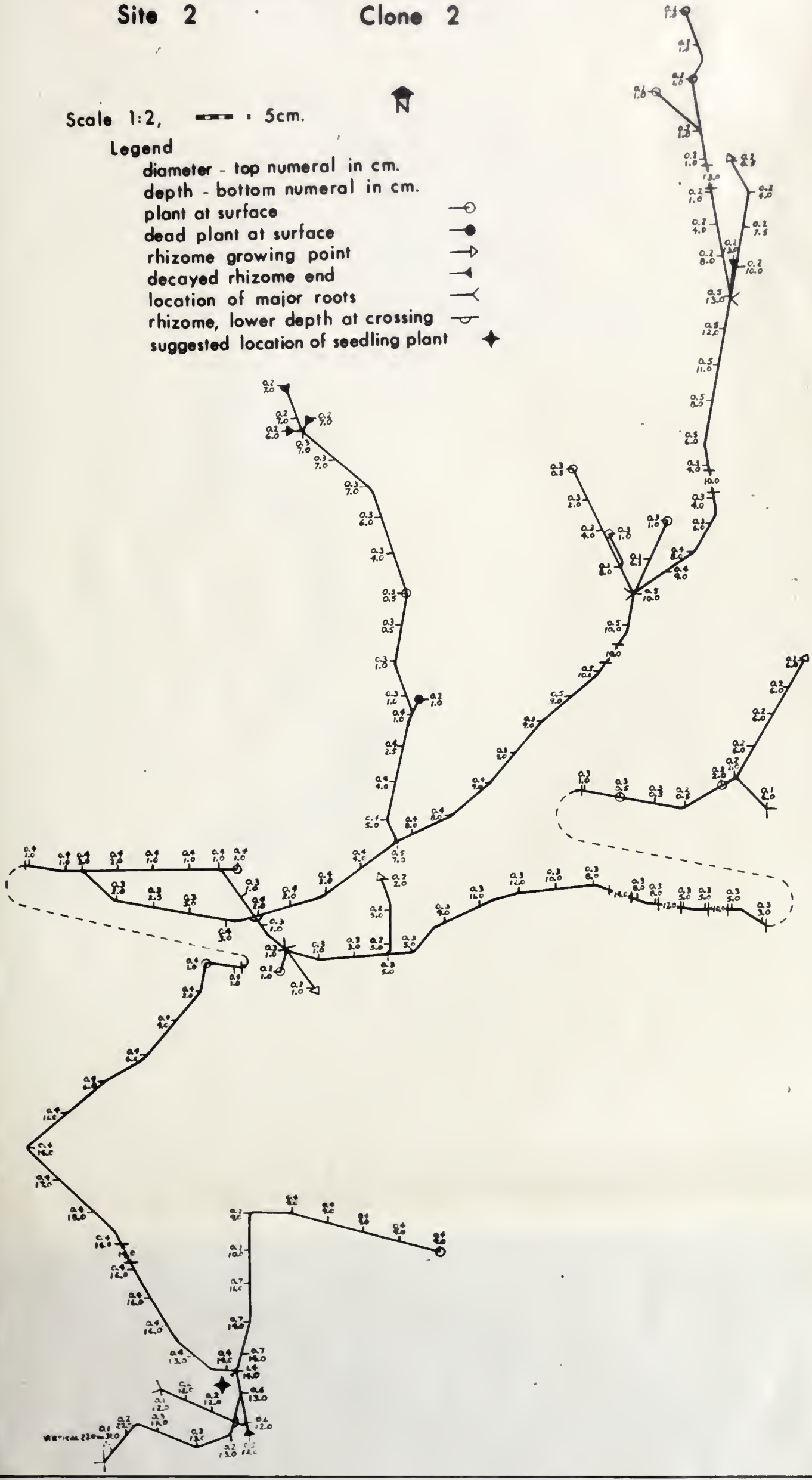


FIG. 6 **RHIZOME MAP *V.canadense***

Site 2 **Clone 3**

Scale 1:2, —— · 5cm. N

Legend

- diameter - top numeral in cm.
- depth - bottom numeral in cm.
- plant at surface
- dead plant at surface
- rhizome growing point
- decayed rhizome end
- location of major roots
- rhizome, lower depth at crossing
- suggested location of seedling plant

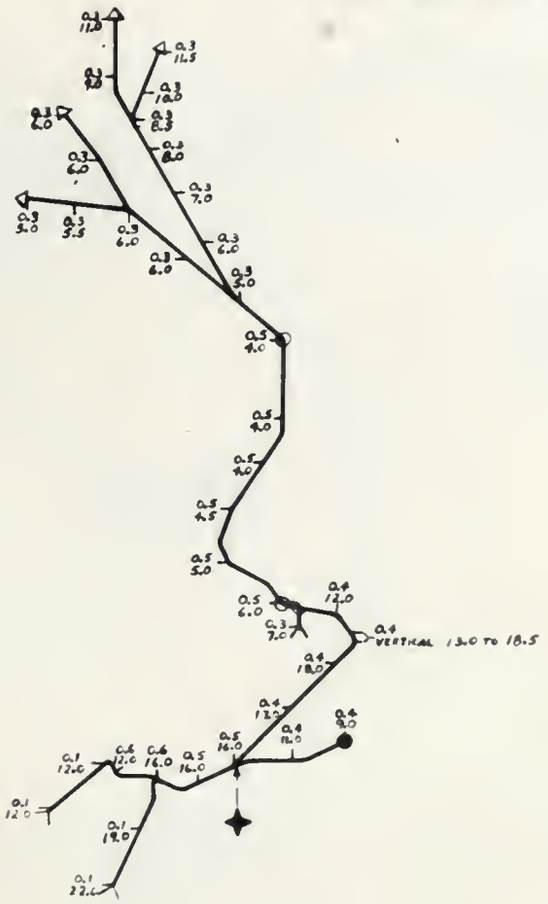


FIG. 7 **RHIZOME MAP *V.canadense***

Site 3 Clone 1

Scale 1:2, — — . 5cm.

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

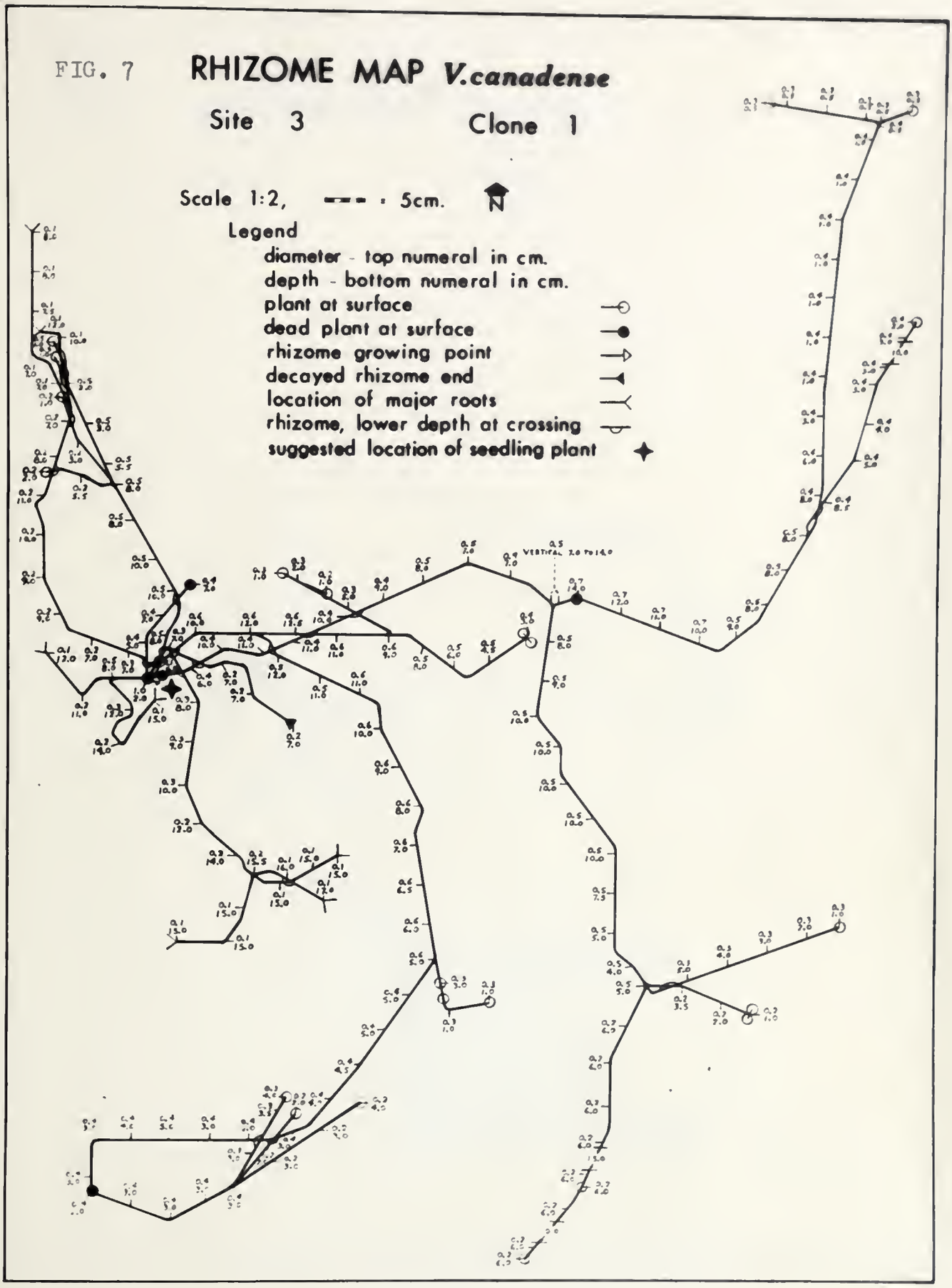
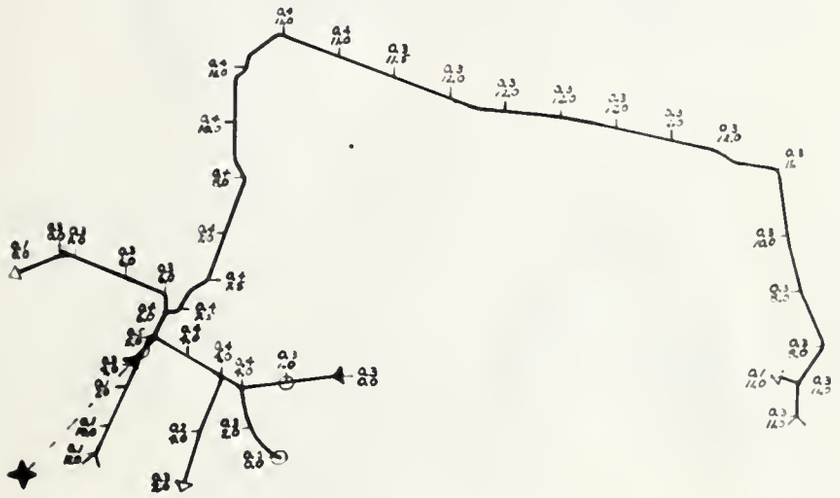


FIG. 8 **RHIZOME MAP** ***V.canadense***

Site 3 Clone 2



Scale 1:2, ▬▬ = 5cm. N

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

FIG. 9 **RHIZOME MAP - *V. canadense***

Site - 3 Clone - 3

Scale 1:2, ▬▬ = 5cm. N

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

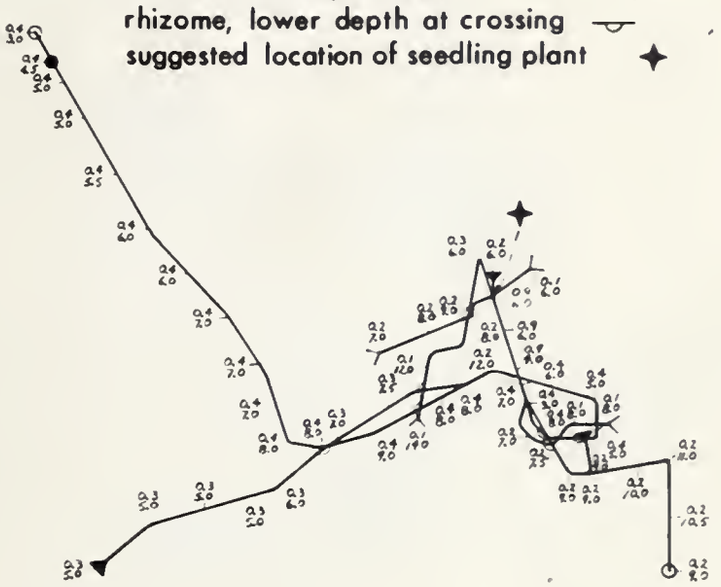
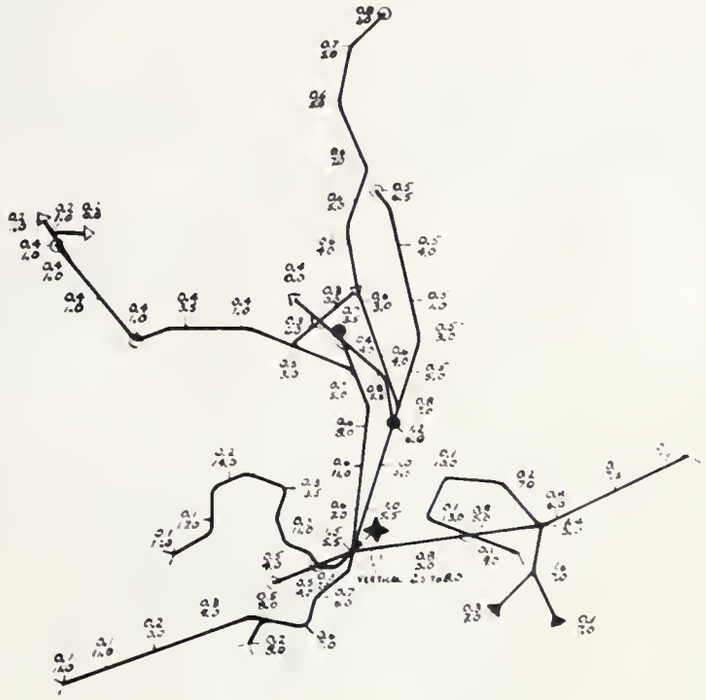


FIG. 10 **RHIZOME MAP** ***V. canadense***

Site 4 Clone 1



Scale 1:2, —— = 5cm. N

Legend

diameter - top numeral in cm.
depth - bottom numerol in cm.
plant at surface
dead plant at surfoce
rhizome growing point
decoyed rhizome end
location of major roots
rhizome, lower depth ot crossing
suggested location of seedling plant

FIG. 11 **RHIZOME MAP *V. canadense***

Site 4 **Clone 2**

Scale 1:2, — · 5cm. N

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

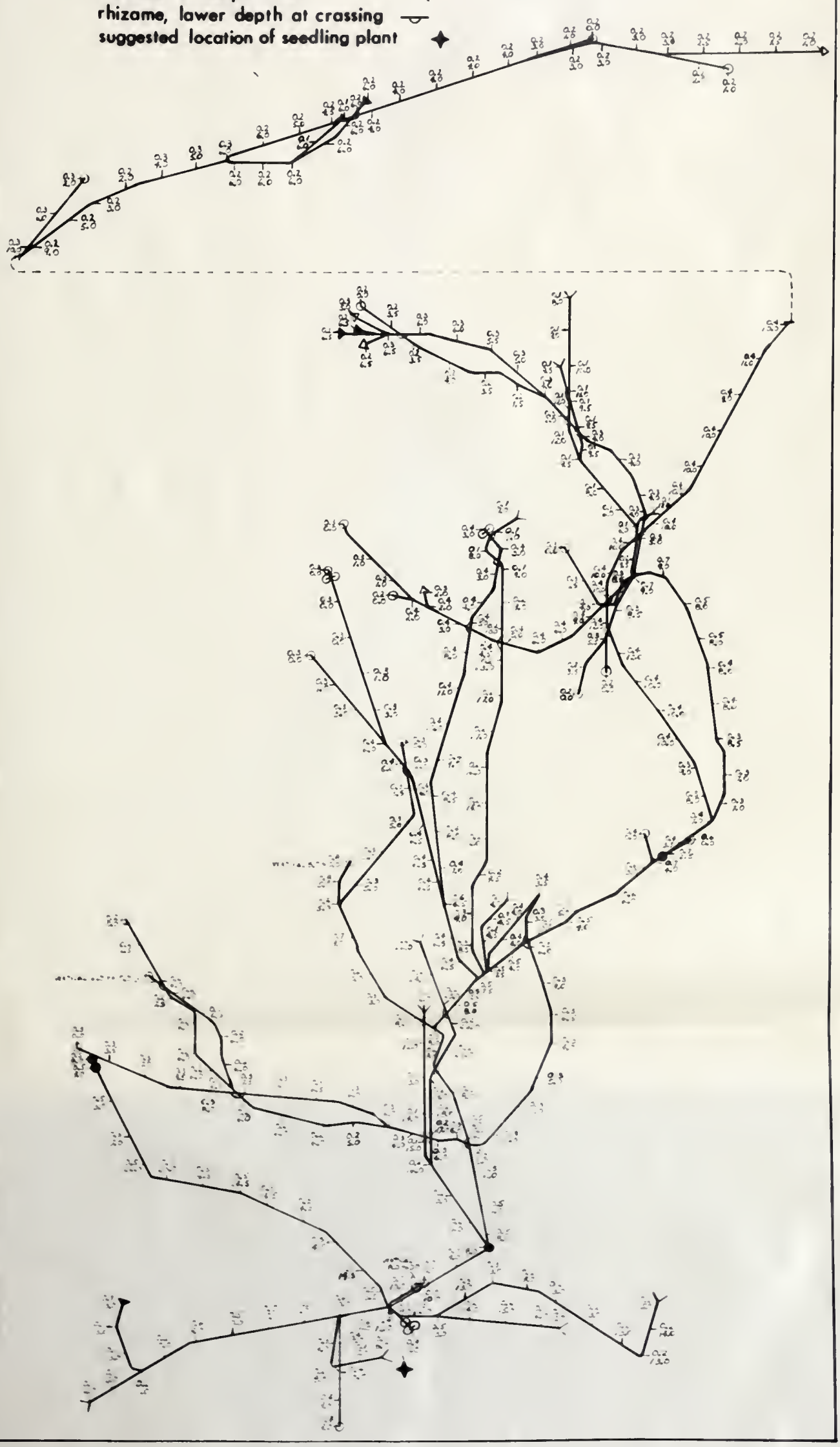


FIG. 12 **RHIZOME MAP** ***V. canadense***

Site 4 **Clone 3**

Scale 1:2, ▬▬ = 5cm. N

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

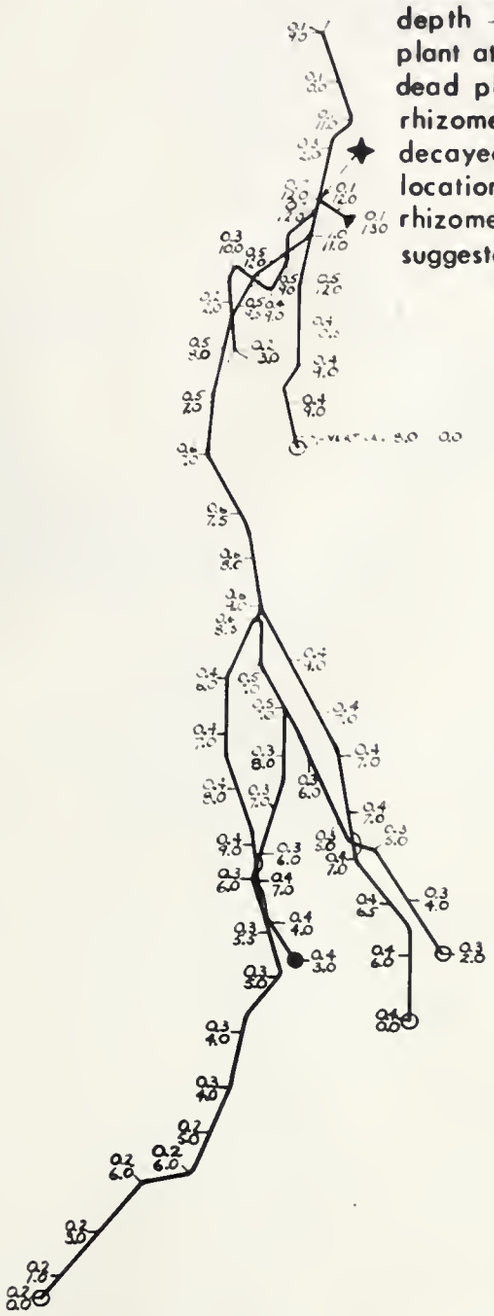


FIG. 13 **RHIZOME MAP *V.canadense***

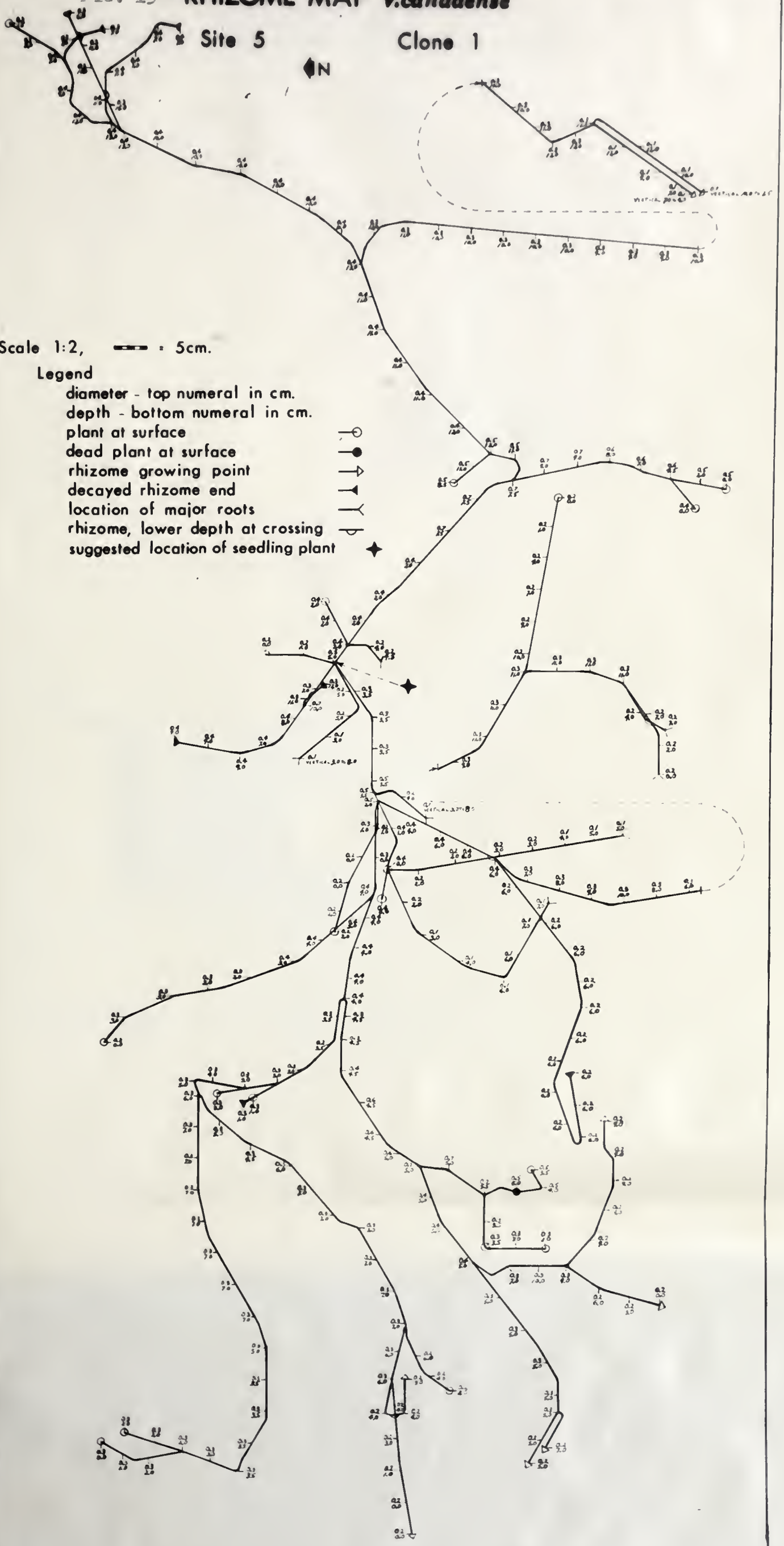
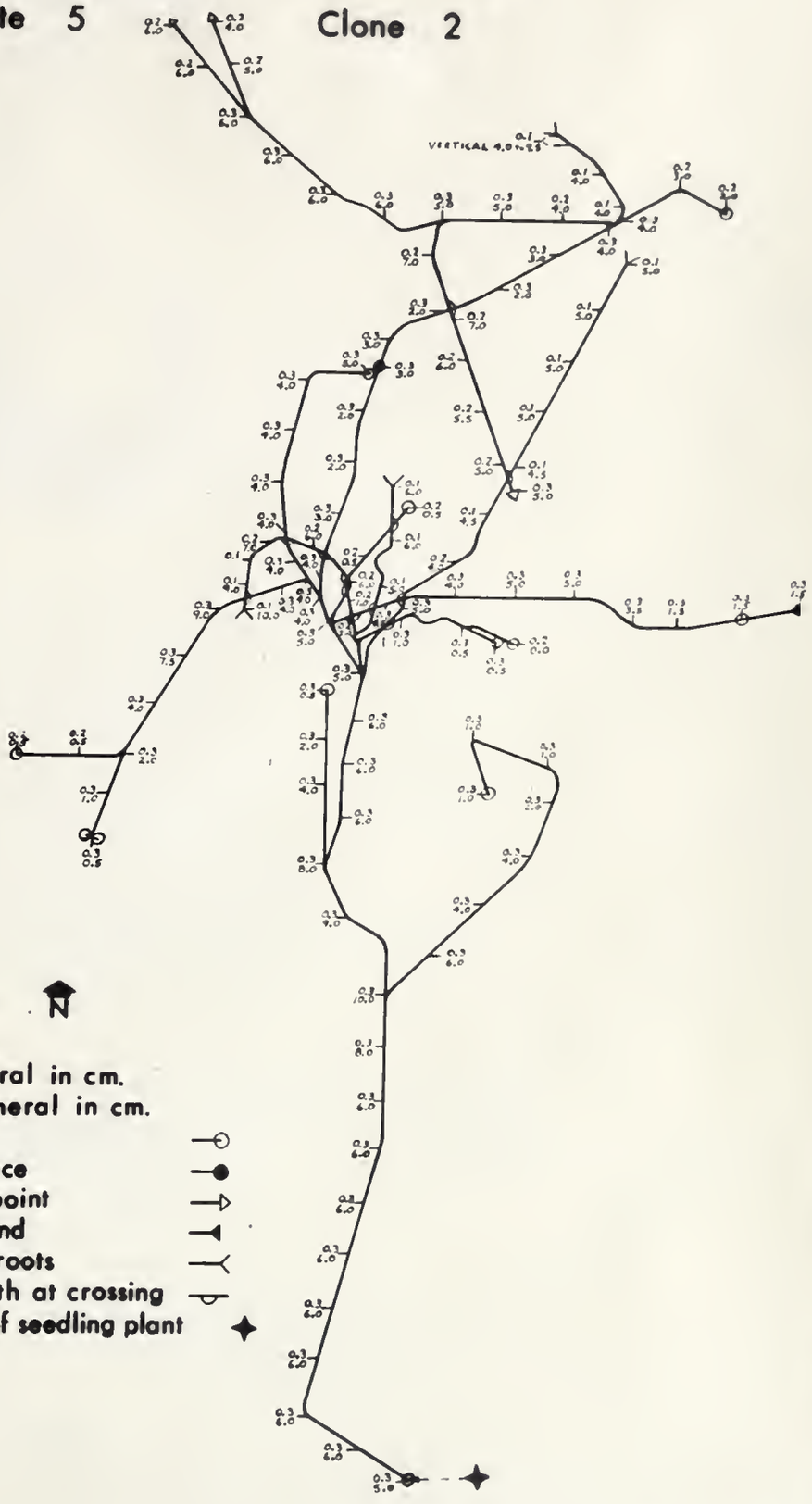


FIG. 14 **RHIZOME MAP *V.canadense***

Site 5 **Clone 2**



Scale 1:2, ▬ = 5cm. N

Legend

- diameter - top numeral in cm.
- depth - bottom numeral in cm.
- plant at surface
- dead plant at surface
- rhizome growing point
- decayed rhizome end
- location of major roots
- rhizome, lower depth at crossing
- suggested location of seedling plant

FIG. 15 **RHIZOME MAP - *V. canadense***

Site - 5 **Clone - 3**

Scale 1:2, — = 5cm. N

Legend

- diameter - top numeral in cm.
- depth - bottom numeral in cm.
- plant at surface
- dead plant at surface
- rhizome growing point
- decayed rhizome end
- location of major roots
- rhizome, lower depth at crossing
- suggested location of seedling plant

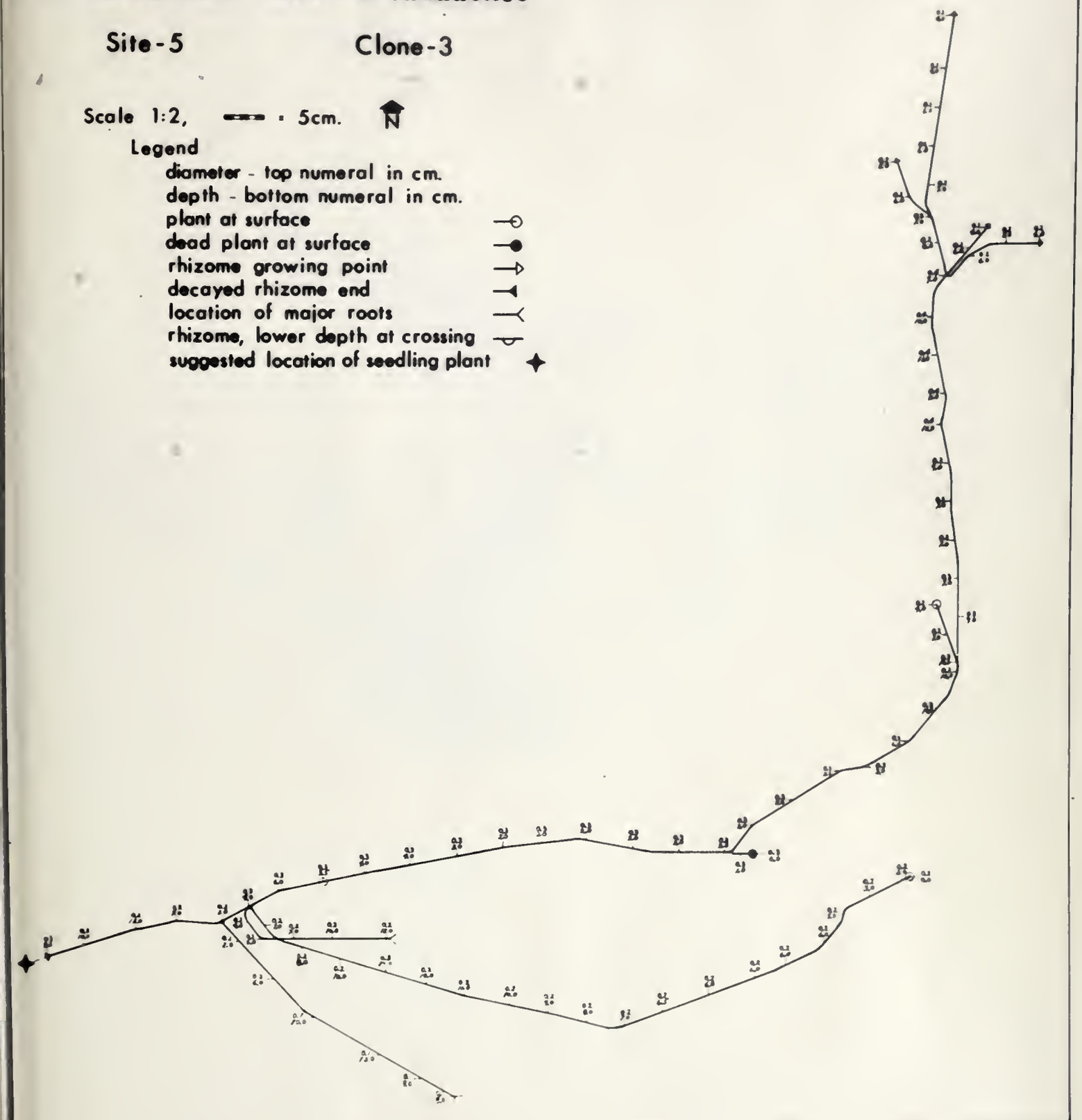


FIG. 16 **RHIZOME MAP** ***V. canadense***

Site 6 **Clone 1**

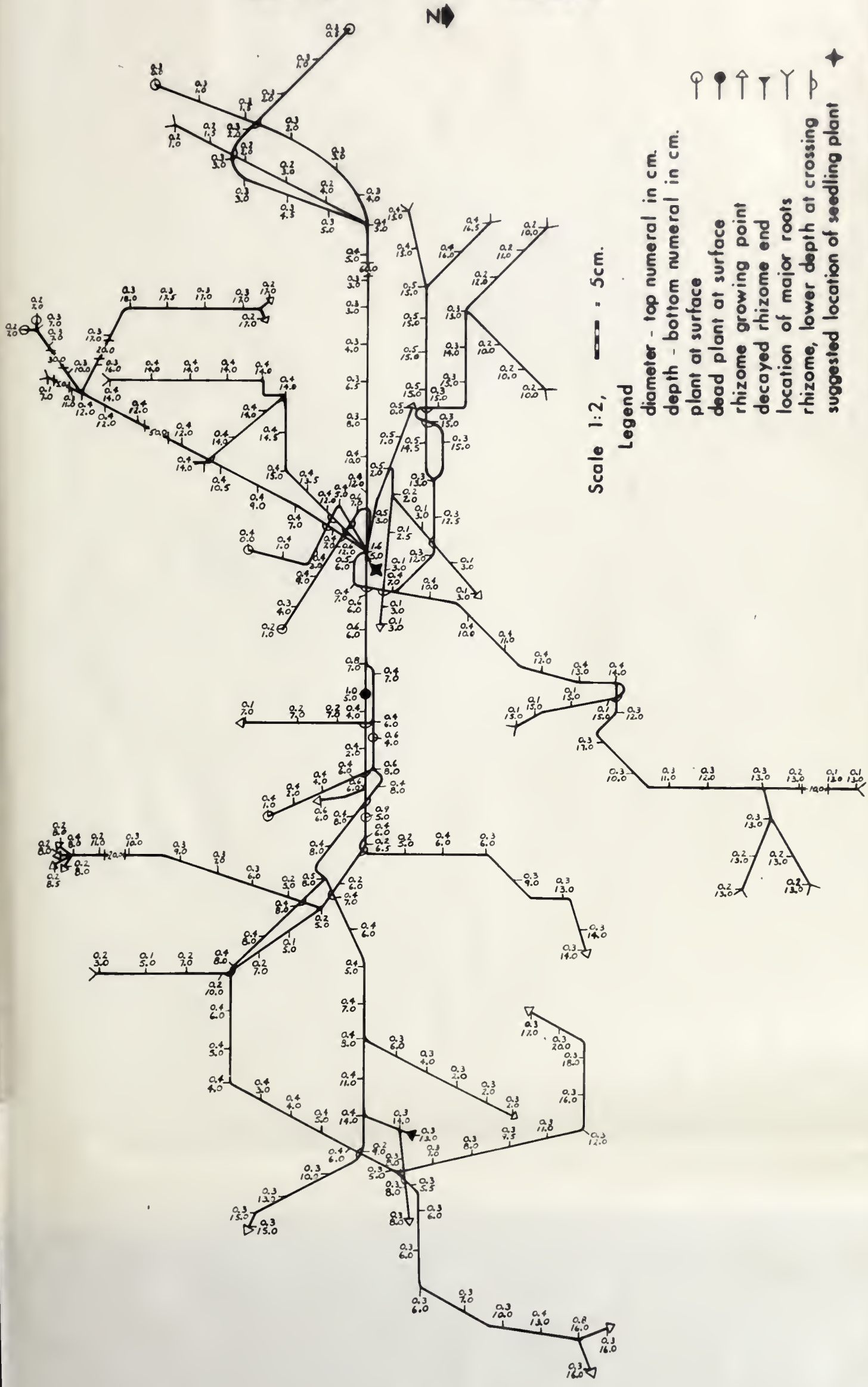


FIG. 17 **RHIZOME MAP *V.canadense***

Site 6 Clone 2

Scale 1:2, — · 5cm. N

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

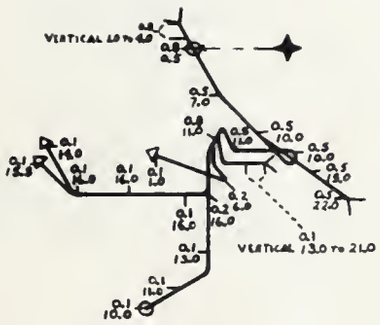


FIG. 18 **RHIZOME MAP** ***V.canadense***

Site 6 Clone 3

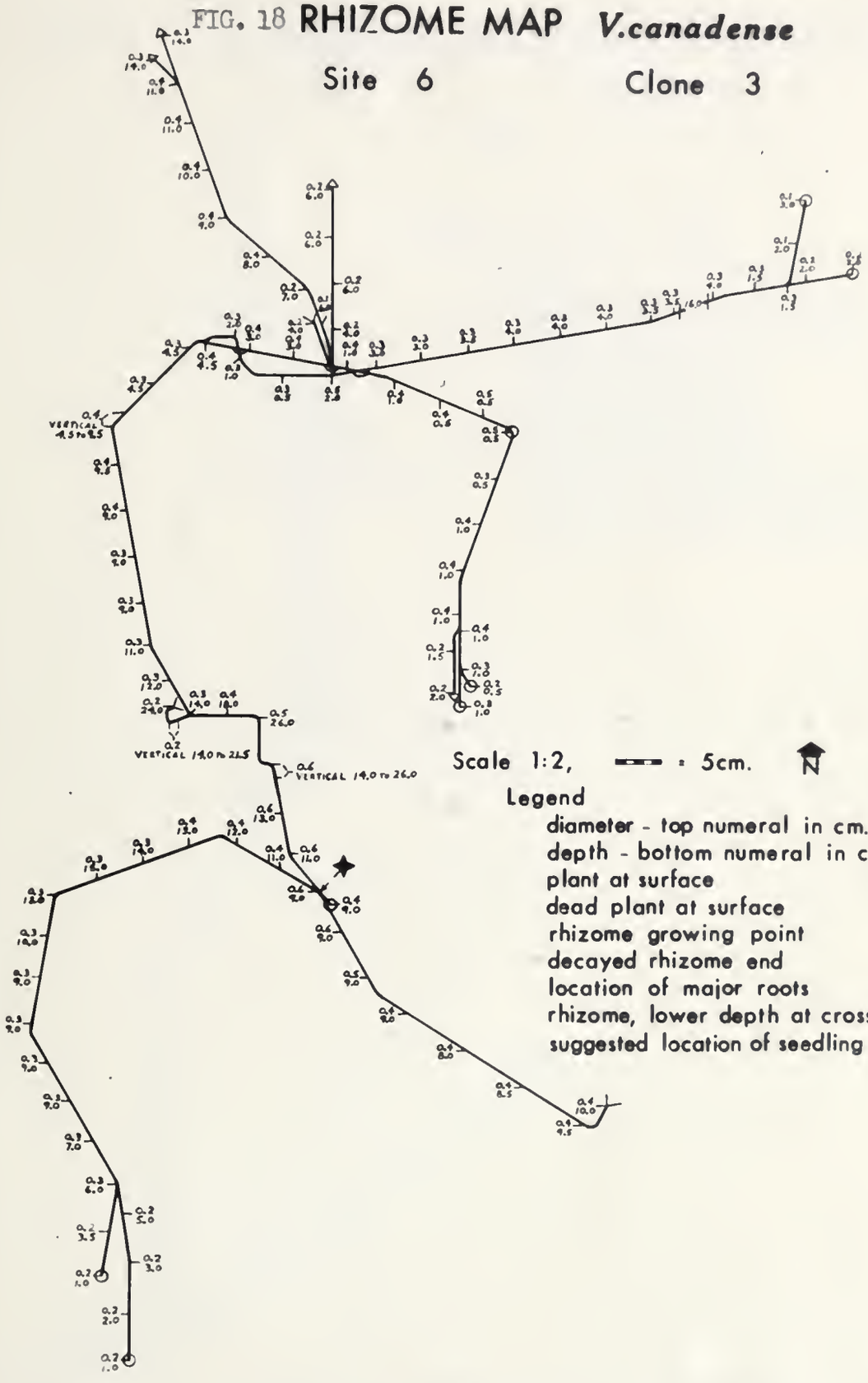


FIG. 19

RHIZOME MAP *V.vitis-idaea* var. *minus*

Site 1 Clone 1

N

Scale 1:2, — — · 5cm.

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

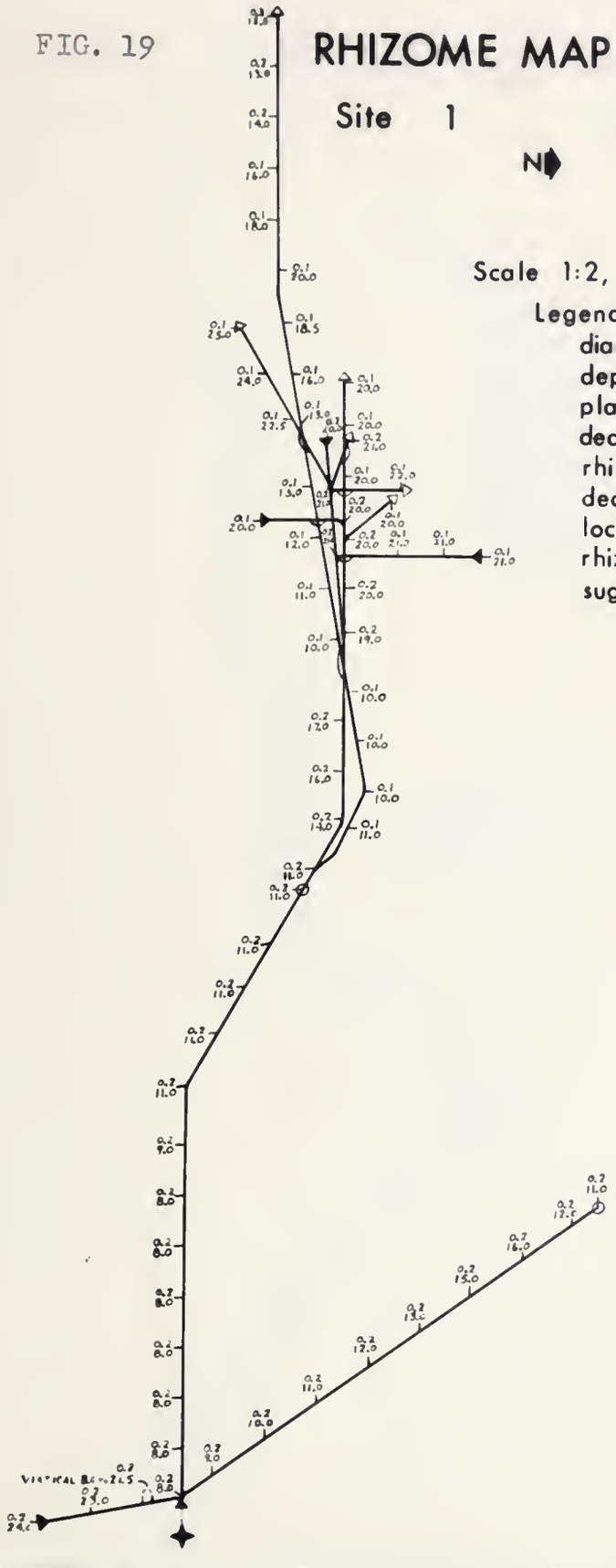


FIG. 20 RHIZOME MAP *V.vitis-idaea* var. *minus*

Site 1 Clone 2

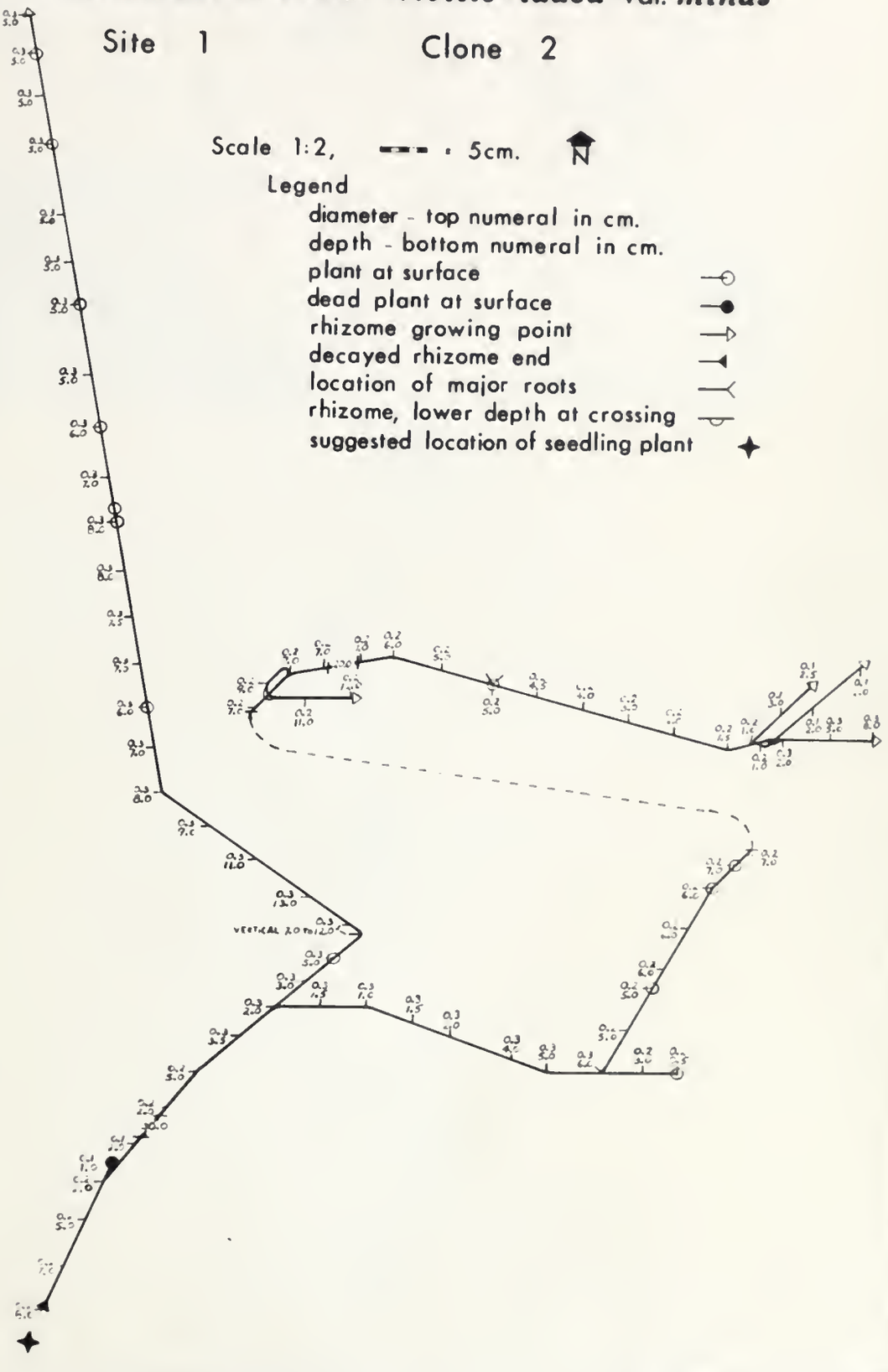


FIG. 21 **RHIZOME MAP** ***V.vitis - idaea*** var. ***minus***

Site 1 Clone 3

Scale 1:2, ▬▬ = 5cm. N

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

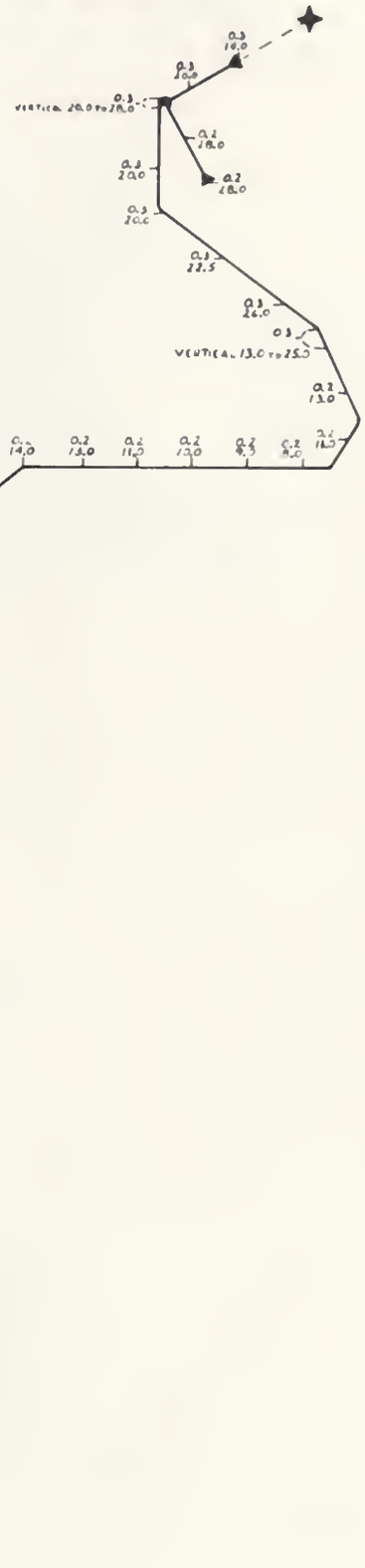


FIG. 22 **RHIZOME MAP** ***V.vitis - idaea*** **var.** ***minus***

Site 2 Clone 1

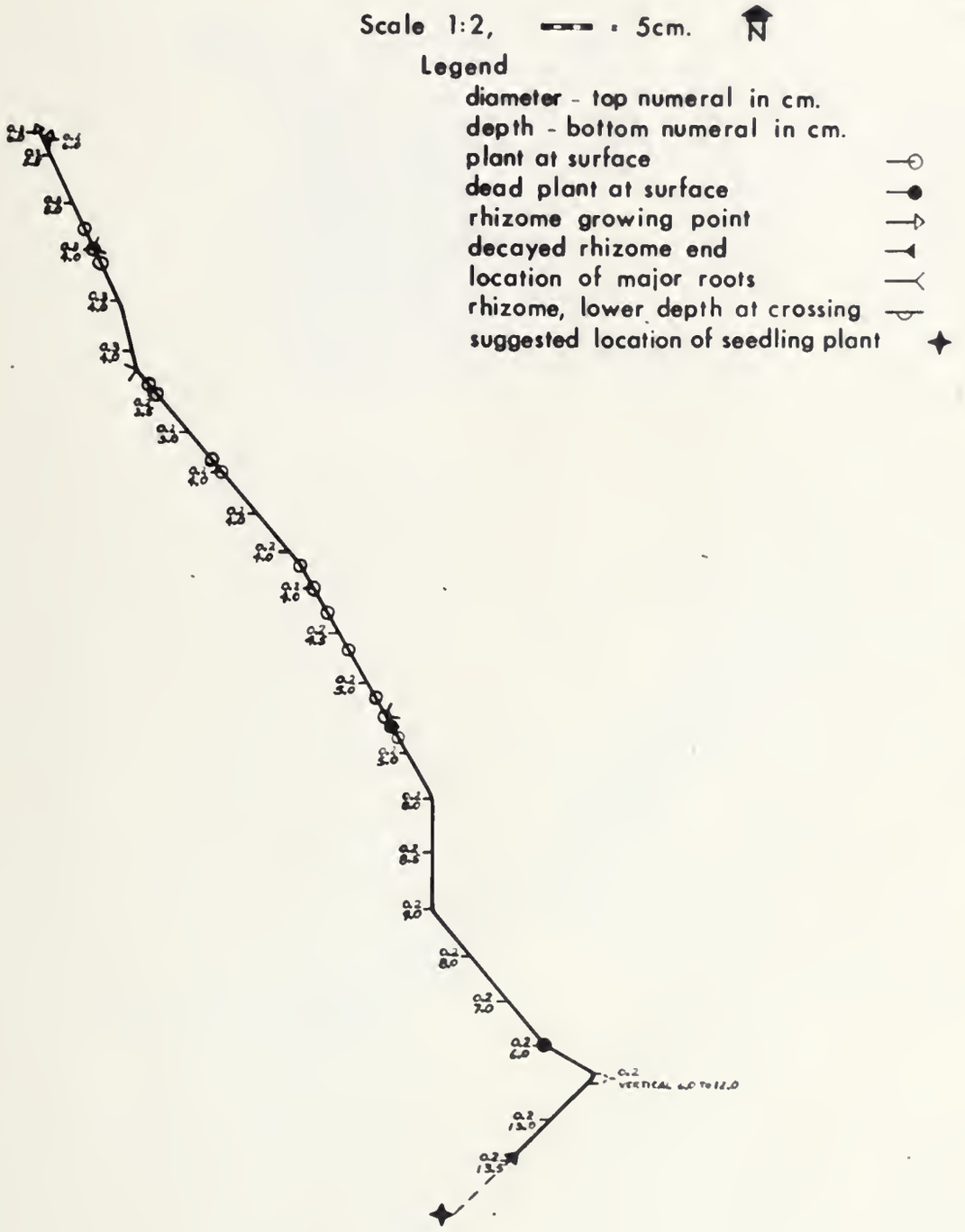


FIG. 23 **RHIZOME MAP *V.vitis - idaea* var. *minus***

Site 2 Clone 2

Scale 1:2, ▬▬ = 5cm. N

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

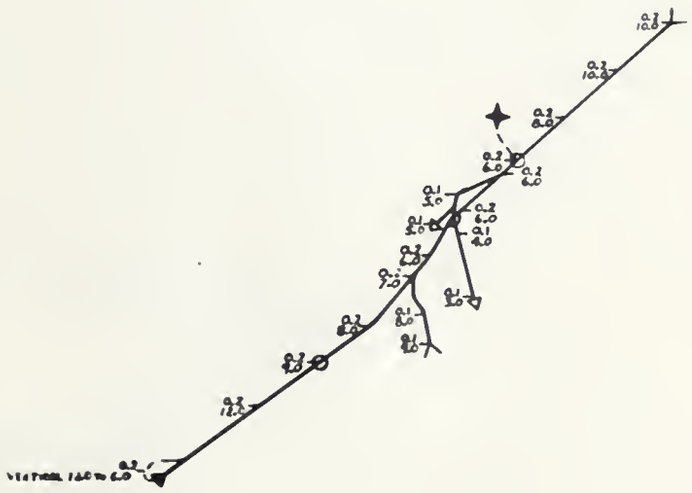


FIG. 24 **RHIZOME MAP *V. vitis-idaea* var. *minus***

Site 2 Clone 3

Scale 1:2, ▬ = 5cm. N

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

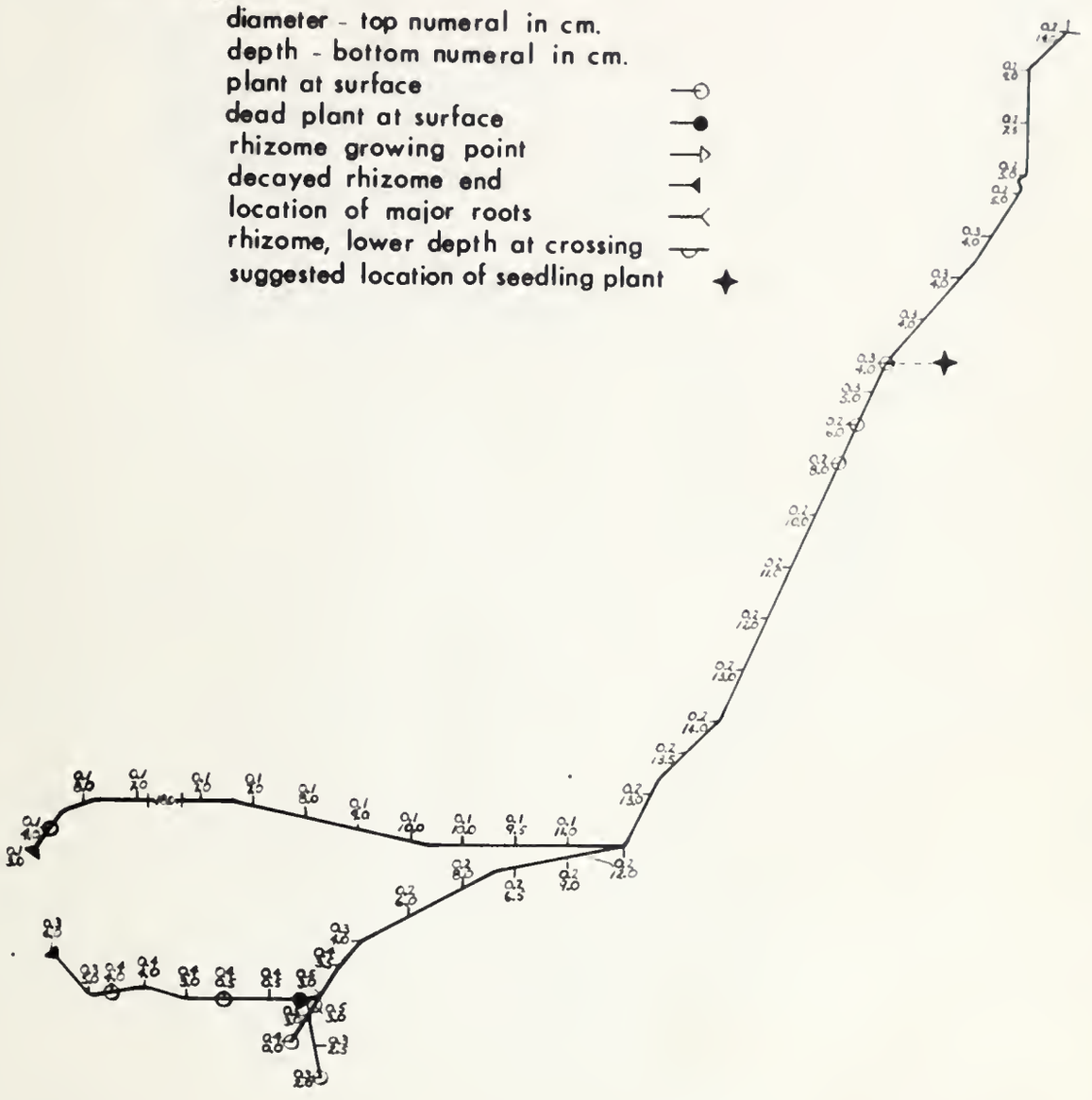


FIG. 25 **RHIZOME MAP** ***V. vitis - idaea*** **var. *minus***

Site 3 Clone 1

N

Scale 1:2, ▬▬ = 5cm.

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

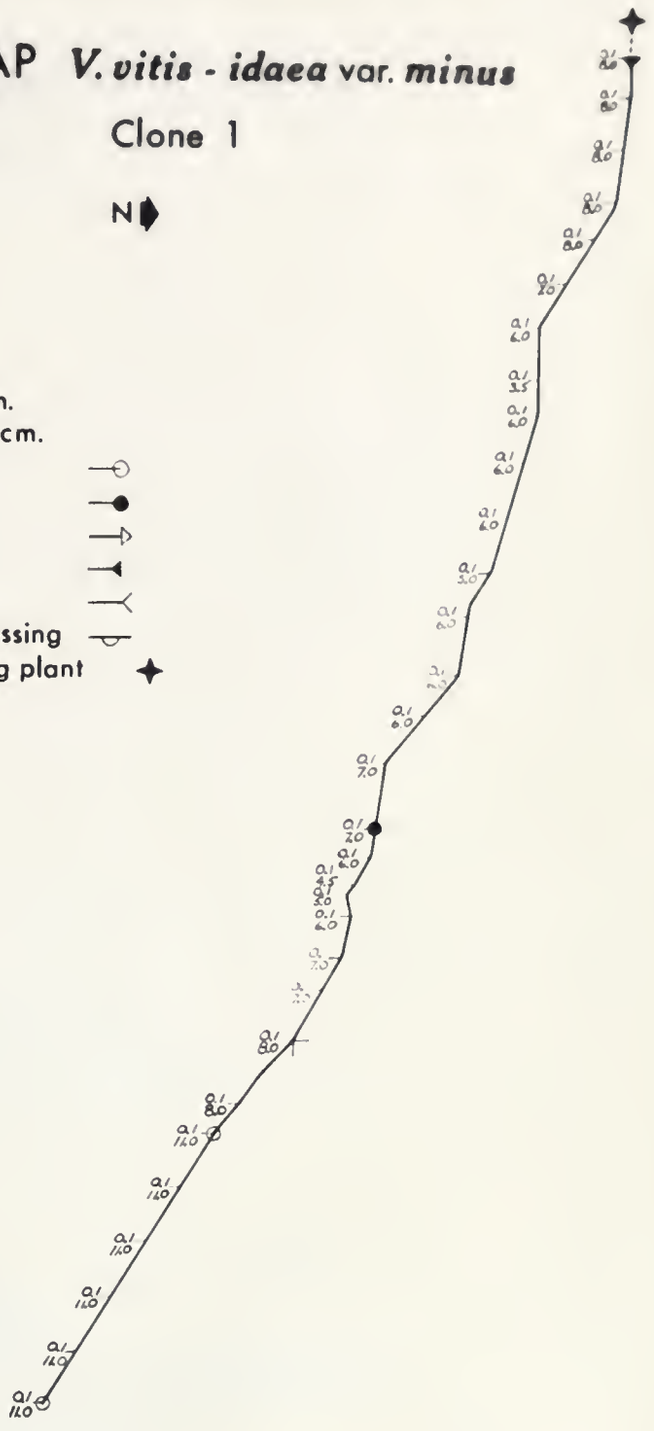
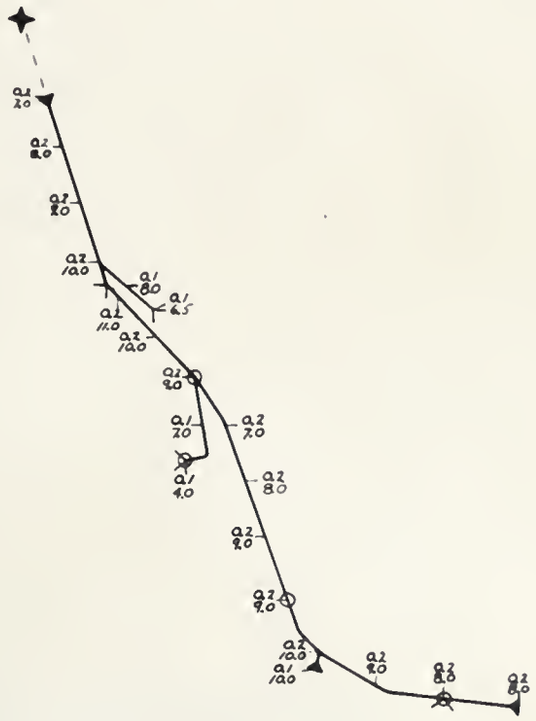


FIG. 26 **RHIZOME MAP - *V.vitis-idaea* var. *minus***

Site 3 Clone 2



Scale 1:2, — • 5cm. N

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

FIG. 27 **RHIZOME MAP *V.vitis-idaea* var. *minus***

Site 3 Clone 3



Scale 1:2, ▬ = 5cm. N

Legend

- diameter - top numerol in cm.
- depth - bottom numerol in cm.
- plant at surface
- dead plant at surface
- rhizome growing point
- decayed rhizome end
- location of major roots
- rhizome, lower depth at crossing
- suggested location of seedling plant

FIG. 28 **RHIZOME MAP** ***V. vitis - idaea*** **var.** ***minus***

Site 4 **Clone 1**

Scale 1:2, — . 5cm.

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

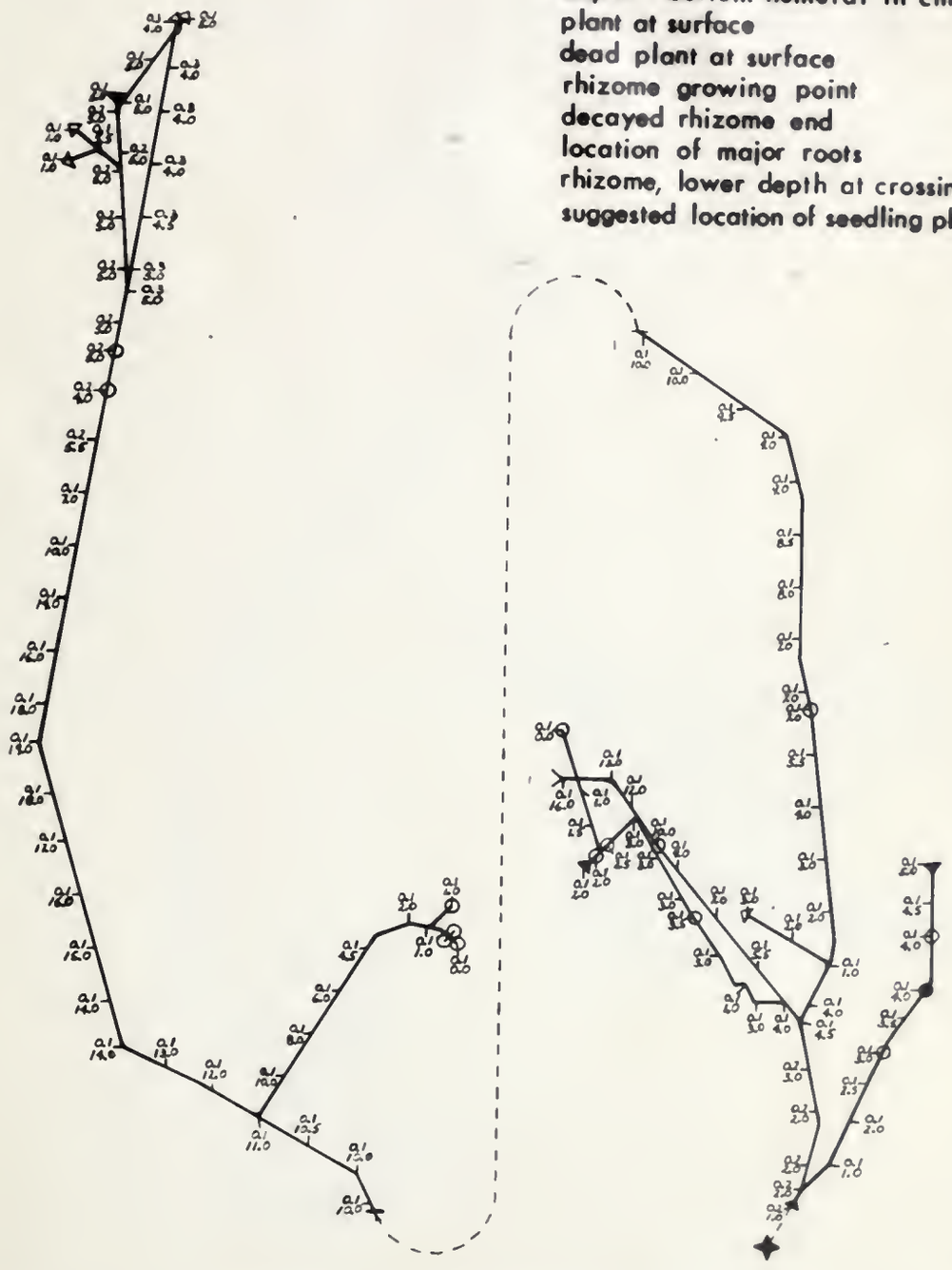


FIG. 29 **RHIZOME MAP** ***V. vitis - idaea*** var. ***minus***

Site 4 **Clone 2**

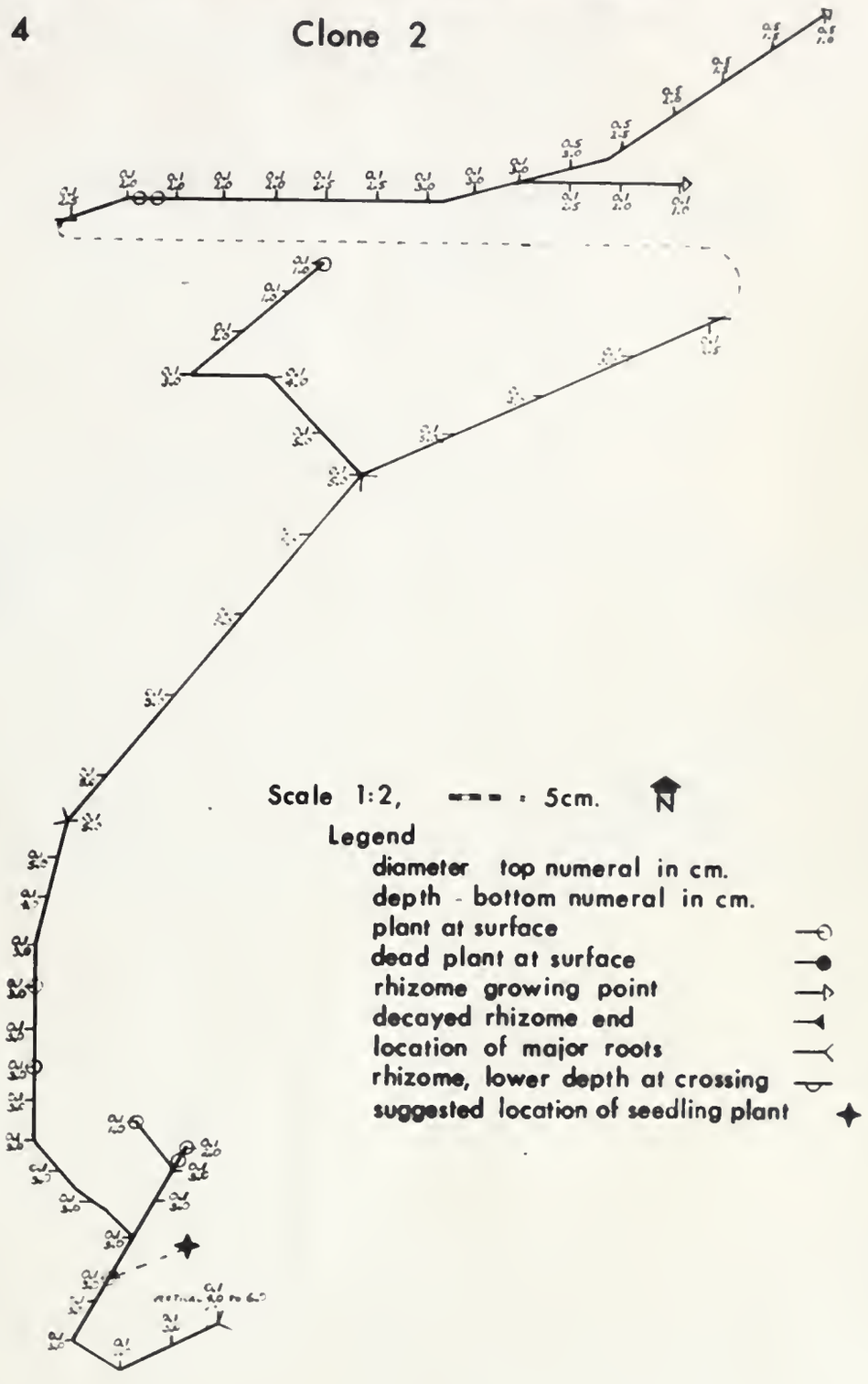
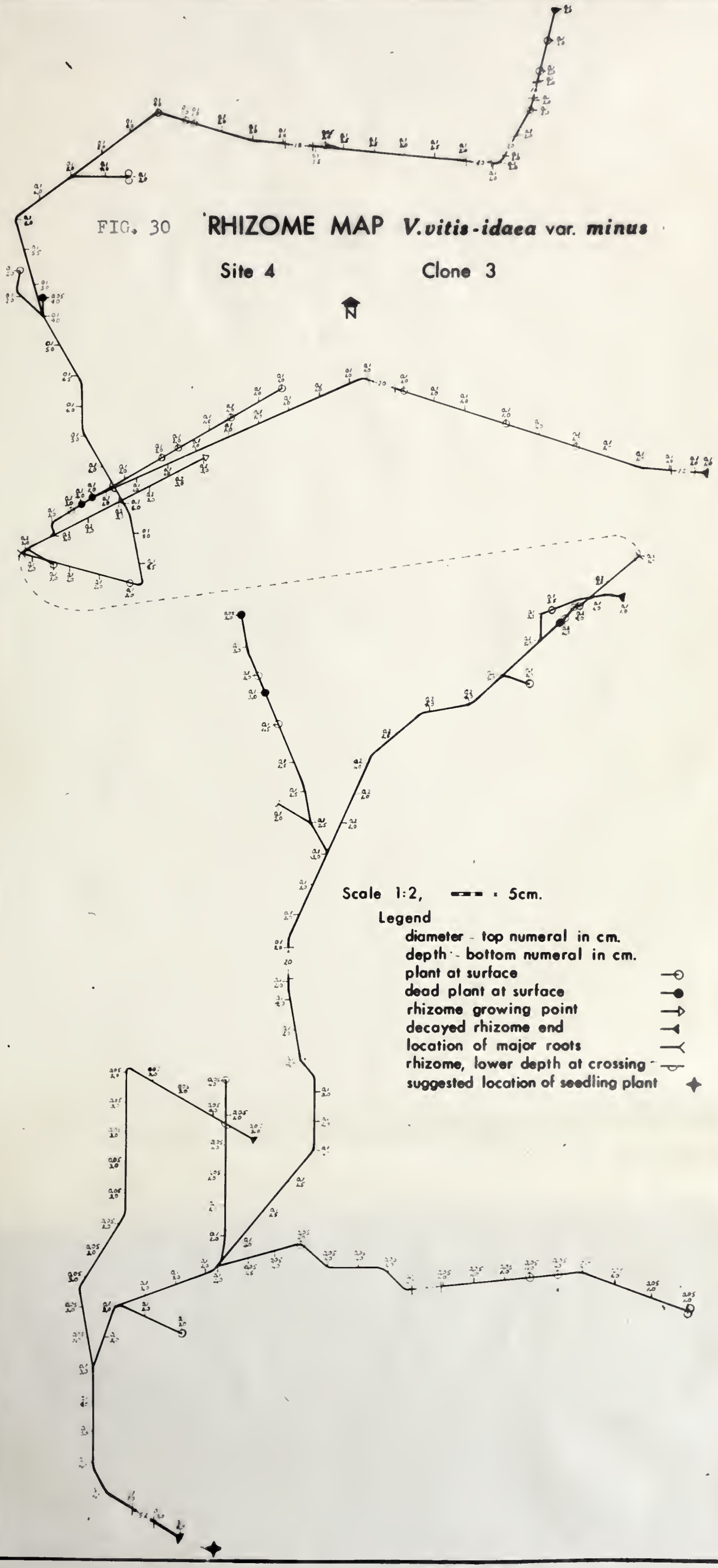


FIG. 30 RHIZOME MAP *V.vitis-idaea* var. *minus*

Site 4 Clone 3



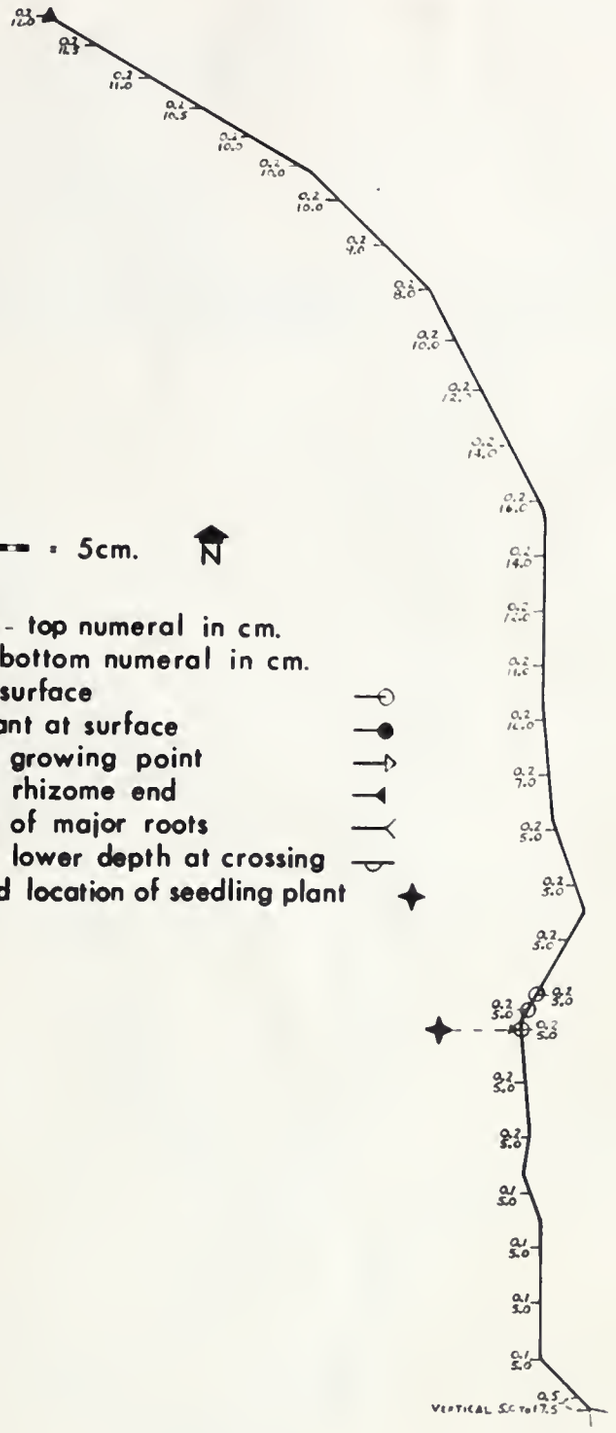
Scale 1:2, ▬▬ = 5cm.

Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

FIG. 31 RHIZOME MAP *V.vitis-idaea* var. *minus*

Site 5 Clone 1



Scale 1:2, ▬ = 5cm. N

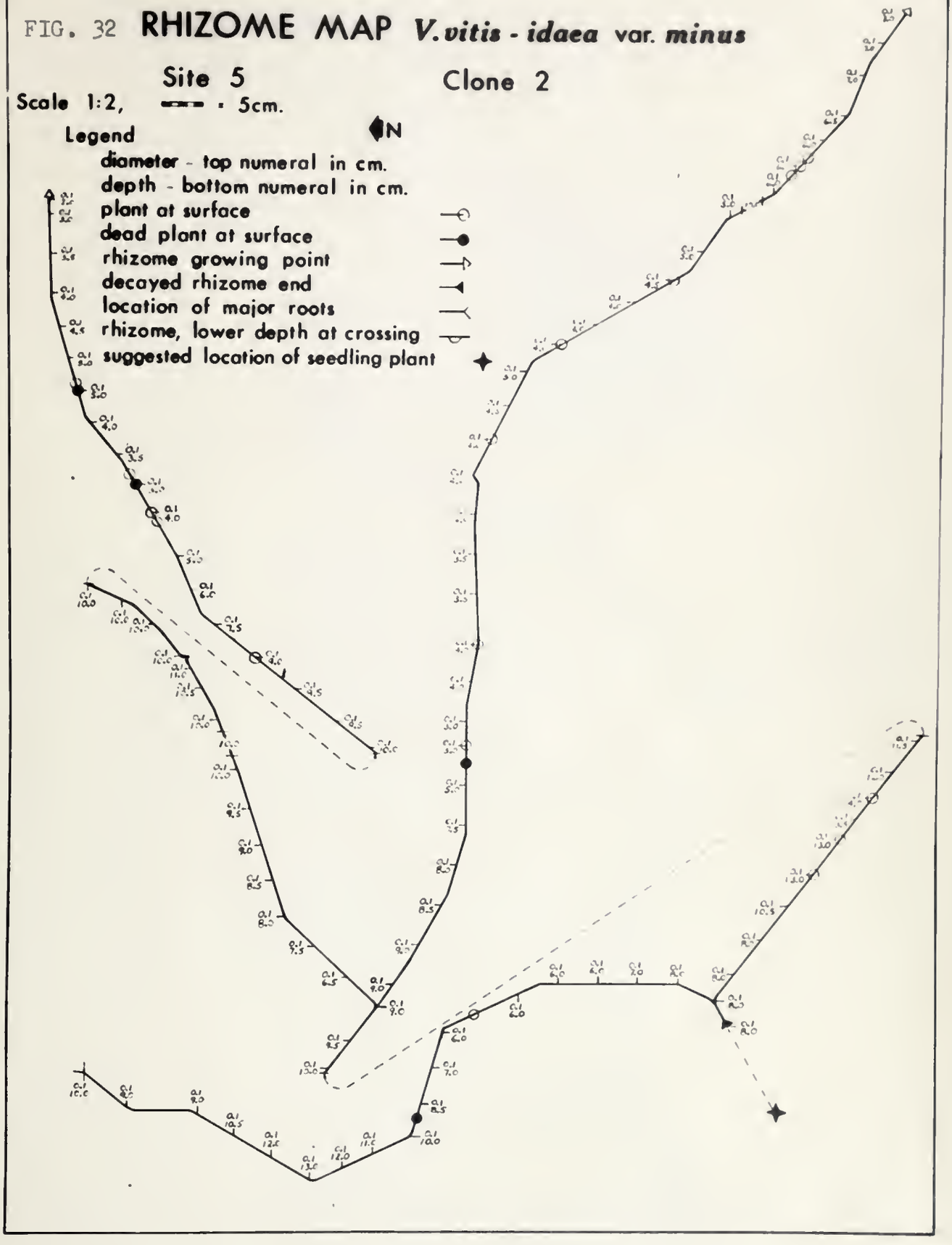
Legend

diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

FIG. 32 **RHIZOME MAP** ***V. vitis - idaea*** **var. *minus***

Site 5 **Clone 2**

Scale 1:2, ——— = 5cm.



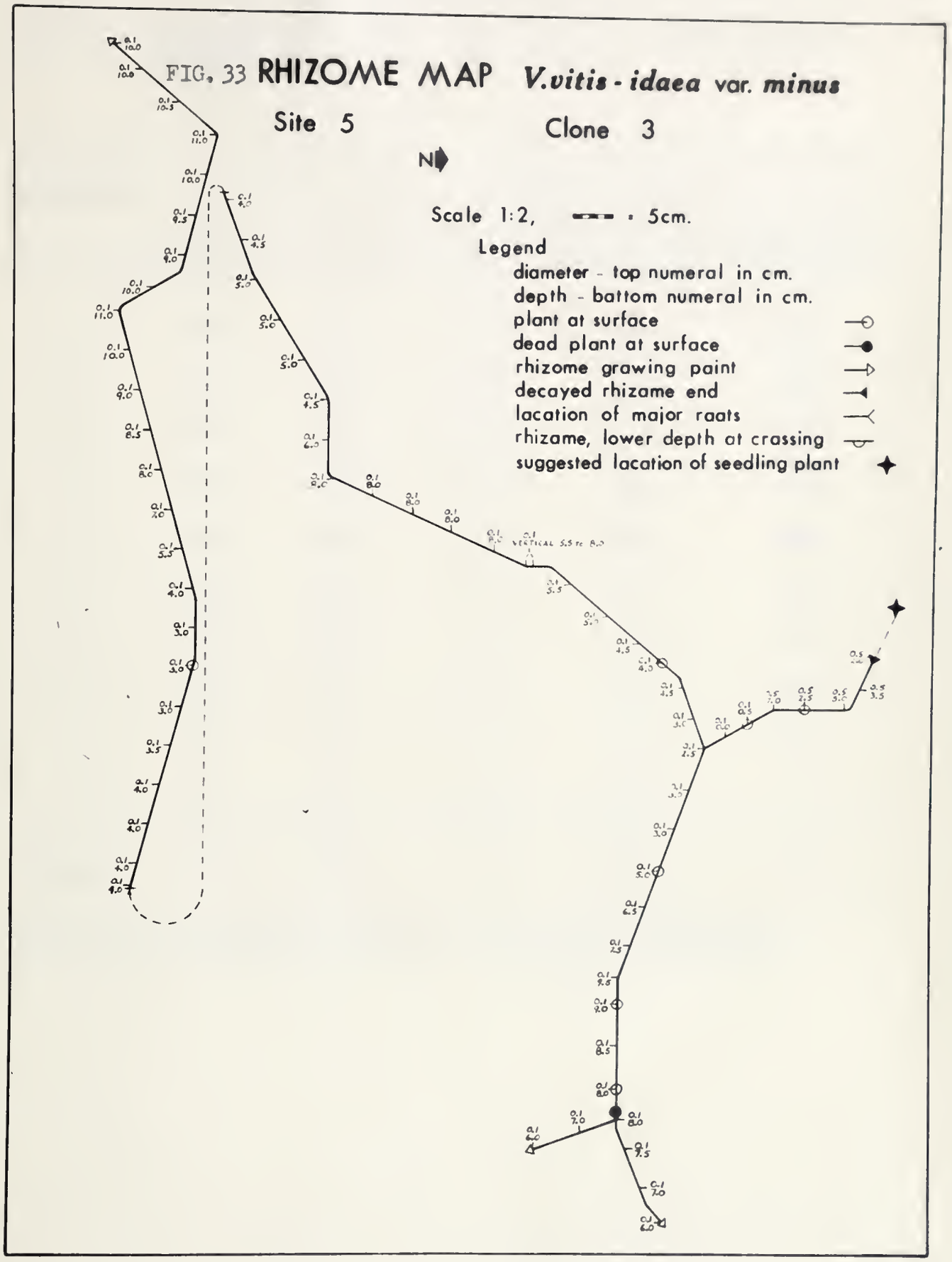

FIG. 33 RHIZOME MAP V.vitis - idaea var. minus
Site 5
Clone 3
N
Scale 1:2, • 5cm.
Legend
diameter - top numeral in cm.
depth - bottom numeral in cm.
plant at surface
dead plant at surface
rhizome growing point
decayed rhizome end
location of major roots
rhizome, lower depth at crossing
suggested location of seedling plant

Table 21. *V. canadense*. PH of leaves during the growing season of 1956

Locations	Dates				
	June 22	July 11	August 12	August 29	September 14
A	3.3	3.8	4.2	4.4	4.5
B	3.2	3.6	4.0	4.2	4.4
C	3.1	3.7	4.1	4.2	4.4
D	3.1	3.7	4.0	4.2	4.2
E	3.1	3.8	4.1	4.3	4.4
F	3.1	3.7	4.0	4.2	4.3
G	3.2	3.8	3.9	4.1	4.1
H	3.2	3.8	4.2	4.2	4.4
I	3.2	3.8	4.1	4.2	4.3
J	3.1	3.8	4.1	4.2	4.3
Average	3.2	3.8	4.1	4.2	4.3

Each figure represents an average of duplicate determinations

Table 22. *V. vitis-idaea* var. *minus*. PH of leaves during the 1956 growing season

Locations	Dates				
	June 22	July 11	August 12	August 29	September 14
A	4.9	4.7	4.7	4.9	5.0
B	4.9	4.6	4.7	4.9	4.9
C	4.9	4.8	4.7	4.8	5.1
D	4.9	4.5	4.5	4.8	5.0
E	4.9	4.9	4.6	4.8	5.0
F	4.5	4.7	4.6	4.8	4.9
G					
H	4.9	4.7	4.8	4.9	5.1
I	4.8	4.6	4.7	4.9	5.0
J					
Average	4.8	4.7	4.6	4.8	5.0

Each figure represents an average of duplicate determinations

Table 23. *V. caespitosum*. PH of leaves during the 1956 growing season

Locations	Dates				
	June 22	July 11	August 12	August 29	September 14
A					
B					
C					
D					
E	3.5	4.0	4.2	4.2	4.4
F	3.7	4.0	4.3	4.3	4.6
G					
H	3.6	4.2	4.5	4.7	4.9
I					
J					
Average	3.6	4.0	4.3	4.4	4.6

Each figure represents an average of duplicate determinations

Table 24. V. canadense. PH of leaves during the 1957 growing season

Locations	Dates				
	June 7	August 2	September 1	September 11	September 26
A	3.6	4.0	4.4	4.4	4.2
B	3.6	4.0	4.3	4.4	4.4
C	3.6	4.0	4.4	4.3	4.0
D	3.6	4.0	4.2	4.2	4.0
E	3.6	4.0	4.2	4.3	4.1
F	3.8	4.0	4.3	4.2	4.1
G	3.8	3.9	4.0	4.1	3.9
H	3.8	4.2	4.4	4.3	4.2
I	3.8	4.0	4.4	4.3	4.2
J	3.7	4.1	4.4	4.3	4.1
Average	3.7	4.0	4.3	4.3	4.1

Each figure represents an average of duplicate determinations

Table 25. V. vitis-idaea var. minus. PH of leaves during the 1957 growing season

Locations	Dates				
	June 7	August 2	September 1	September 11	September 26
A	5.0	4.6	5.1	4.9	5.1
B	5.0	4.8	4.9	5.0	5.1
C	5.0	4.7	5.0	5.0	5.2
D	5.0	4.8	4.9	4.8	5.0
E	5.1	4.8	5.1	5.0	5.2
F	5.2	4.8	5.1	5.0	5.0
G					
H	5.2	4.9	5.1	5.0	5.1
I	5.0	4.8	4.8	5.0	4.9
Average	5.1	4.8	5.0	5.0	5.1

Each figure represents an average of duplicate determinations

Table 26. V. caespitosum. PH of leaves during the 1957 growing season

Locations	Dates				
	June 7	August 2	September 1	September 11	September 26
A					
B	3.7	4.2	4.6	4.6	4.4
C	3.6	4.4	4.8	4.6	4.5
D	3.6	4.0	4.5	4.6	4.4
E	3.9	4.0	4.6	4.6	4.6
F	3.8	4.0	4.4	4.4	4.6
G					
H	3.8	4.4	4.8	4.7	4.8
I	3.8	3.9	4.3	4.6	4.4
J					
Average	3.7	4.1	4.6	4.6	4.5

Each figure represents an average of duplicate determinations

Table 27. Analyses in p.p.m. and pH of composite soil samples from locations A to E

Locations	Soil Horizons	NO_3	NH_4	P	K	Al	Fe	Ca	Mg	SO_4	pH
A	A_{oo}	nil	10.0	5.5	30.0	nil	trace	10.0	trace	nil	4.5
	A_2	nil	trace	13.0	5.0	1.0	trace	10.0	nil	nil	4.4
	B_1	nil	20.0	19.0	30.0	1.0	trace	nil	nil	nil	5.0
	B_2	nil	25.0	11.5	40.0	1.0	trace	10.0	nil	trace	5.7
	C	nil	trace	5.0	1.0	nil	nil	10.0	2.0	nil	6.0
B	A_{oo}	1.0	4.0	7.0	30.0	nil	nil	100.0	3.0	nil	6.0
	A_o	nil	2.0	7.5	12.0	nil	trace	40.0	2.0	nil	5.7
	A_2	nil	2.0	6.5	1.0	nil	2.0	40.0	trace	nil	5.5
	B_1	nil	trace	3.5	5.0	trace	2.0	40.0	trace	nil	5.2
	B_2	nil	trace	2.0	7.0	trace	nil	40.0	trace	nil	5.0
	C	nil	nil	2.0	1.0	trace	nil	trace	1.0	nil	5.4
C	A_{oo}	nil	10.0	8.5	35.0	nil	nil	100.0	3.0	nil	5.9
	A_o	nil	5.0	13.5	15.0	nil	trace	40.0	1.0	nil	5.8
	B_1	nil	2.0	6.5	10.0	trace	trace	70.0	1.0	nil	6.3
	B_2	nil	trace	2.0	10.0	trace	trace	30.0	trace	nil	6.4
	C	nil	trace	3.0	6.0	trace	trace	trace	trace	nil	6.0
D	A_{oo}	trace	25.0	3.5	35.0	nil	trace	trace	2.0	nil	5.6
	A_o	nil	8.0	2.0	25.0	nil	trace	trace	trace	nil	5.1
	A_2	nil	2.0	1.5	10.0	nil	trace	nil	trace	nil	5.2
	B_2	nil	2.0	1.5	7.0	2.0	trace	nil	nil	nil	5.2
	C	nil	2.0	1.0	5.0	nil	trace	nil	nil	nil	5.6
E	A_{oo}	1.5	20.0	7.0	40.0	nil	nil	40.0	3.0	nil	6.2
	A_o	nil	18.0	5.5	30.0	nil	trace	trace	2.0	nil	5.6
	A_2	nil	6.0	6.0	15.0	nil	trace	trace	1.0	nil	5.6
	B_2	nil	2.0	10.0	5.0	nil	trace	nil	trace	nil	5.6
	C_1	nil	4.0	1.0	5.0	nil	trace	trace	3.0	nil	5.9
	C_2	nil	2.0	3.0	trace	trace	trace	nil	1.0	nil	8.4

Data represents an average of duplicate determinations

Table 27 (continued). Analyses in p.p.m. and pH of composite soil samples from locations F to J

Locations	Soil Horizons	NO_3	NH_4	P	K	Al	Fe	Ca	Mg	SO_4	pH
F	A_{oo}	2.5	25.0	17.5	40.0	nil	trace	trace	4.0	nil	5.7
	A_o	nil	2.0	17.0	22.0	1.0	trace	trace	1.0	nil	5.0
	B_1	nil	trace	12.5	8.0	1.0	trace	trace	trace	nil	5.6
	B_2	nil	nil	5.0	5.0	trace	nil	trace	1.0	nil	6.0
	C	nil	nil	3.5	5.0	nil	nil	trace	trace	nil	6.0
G	A_{oo}	3.0	8.0	8.0	35.0	nil	nil	100.0	3.0	nil	6.1
	A_2	nil	trace	5.5	5.0	2.0	trace	nil	nil	nil	5.2
	B_2	nil	trace	7.0	10.0	nil	trace	trace	trace	nil	5.6
	C	nil	trace	3.0	5.0	nil	nil	nil	trace	nil	5.9
H	A_{oo}	nil	20.0	10.0	40.0	nil	nil	trace	2.0	nil	5.3
	A_o	nil	trace	4.5	8.0	nil	trace	nil	trace	nil	4.8
	A_2	nil	trace	4.0	trace	trace	trace	nil	trace	nil	4.6
	B_2	nil	trace	7.0	trace	nil	trace	trace	1.0	nil	6.4
	C	nil	trace	1.0	trace	nil	trace	trace	trace	nil	7.4
I	A_{oo}	1.0	10.0	14.5	35.0	nil	nil	150.0	3.0	nil	6.6
	A_o	nil	4.0	5.0	20.0	nil	trace	40.0	2.0	nil	6.1
	A_2	nil	2.0	2.0	5.0	nil	trace	nil	trace	nil	5.4
	B_2	nil	2.0	11.0	10.0	trace	trace	nil	trace	nil	5.3
	C	nil	nil	2.0	5.0	nil	nil	nil	1.0	nil	5.9
J	A_{oo}	nil	2.0	5.0	34.0	trace	trace	40.0	4.0	nil	6.0
	A_o	nil	1.0	2.0	12.0	nil	nil	30.0	1.0	nil	5.8
	A_2	nil	1.0	4.0	7.0	trace	nil	30.0	2.0	nil	5.4
	B_2	nil	1.0	11.0	3.0	nil	trace	20.0	1.0	nil	5.1
	C	nil	trace	4.0	6.0	nil	trace	160.0	4.0	nil	5.4

Data represents an average of duplicate determinations

Table 28. The effect of soil amendment chemicals on soil reaction

Amendments	Treatments	Application per 1000 gms. of soil	pH*	
			November 18	November 26
Sulfuric acid	1	leached with 10.0 N	3.2	3.3
" "	2	" " 1.0 N	3.5	3.7
" "	3	" " 0.5 N	4.0	4.0
" "	4	" " 0.1 N	5.2	5.3
No treatment			6.3	6.2
Calcium hydroxide	1	0.3 gms.	6.6	6.7
" "	2	0.9 gms.	6.8	6.7
" "	3	1.2 gms.	6.9	6.9
" "	4	1.8 gms.	7.0	6.9
" "	5	2.1 gms.	7.6	7.5

*Each figure represents an average of duplicate determinations

Table 29. Nutrient level in p.p.m. of soil amended with sulfuric acid and calcium hydroxide, December, 1956

Amendment		Application per 1000 gm. of soil			NO_3	NH_4	P	K	Al	Fe	Ca	Mg	SO_4
Sulfuric acid	1	leached with	10.0	N	nil	5	1	4	3	trace	nil	nil	200
" "	2	" "	1.0	N	nil	4	1	3	1	1	nil	nil	100
" "	3	" "	0.5	N	nil	8	2	4	trace	trace	trace	nil	100
" "	4	" "	0.1	N	nil	6	1	6	nil	trace	nil	1	70
No treatment					trace	6	1	8	nil	trace	60	nil	nil
Calcium hydroxide	1	0.3 gms.			1	4	1	8	nil	trace	60	nil	nil
" "	2	0.9 gms.			6	5	1	8	nil	trace	75	nil	nil
" "	3	1.2 gms.			7	4	1	7	nil	trace	100	nil	nil
" "	4	1.8 gms.			4	6	1	8	nil	nil	100	nil	nil
" "	5	2.1 gms.			5	7	1	6	nil	nil	150	nil	nil

Each figure represents an average of duplicate determination

Table 30. Soil analysis in p.p.m. of amended soil treatments. Analysis carried out on February 9, 1957 (1) and November 1, 1958 (2)

Treatments	NO_3		NH_4		P		K		Al		Fe		Ca		Mg		SO_4	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	nil	trace	4	3	3	8	5	12	1	1	trace	1	nil	35	nil	2	35	100
2	nil	trace	6	2	4	11	6	16	nil	nil	trace	2	nil	65	nil	3	25	40
3	trace	2	5	4	2	10	8	18	nil	nil	trace	1	60	130	nil	3	nil	nil
4	2	5	5	3	4	9	8	16	nil	nil	trace	1	100	180	nil	2	nil	nil
5	4	4	6	2	2	8	7	17	nil	nil	nil	1	150	200	nil	1	nil	nil

Each figure represents the average of the determinations of duplicate treatments

Table 31. Soil analysis in p.p.m. of amended soil treatments. Analysis carried out on March 6, 1957 (1) and November 1, 1958 (2)

Treatments	NO_3		NH_4		P		K		Al		Fe		Ca		Mg		SO_4	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	nil	trace	5	5	7	12	4	12	nil	trace	trace	1	nil	20	nil	1	55	110
2	nil	nil	6	trace	6	13	5	9	nil	nil	trace	1	nil	50	nil	2	25	45
3	trace	trace	5	nil	3	10	6	8	nil	nil	trace	trace	40	115	nil	2	nil	nil
4	1	3	3	nil	5	12	7	7	nil	nil	trace	trace	100	115	nil	2	nil	nil
5	4	4	4	nil	7	13	7	7	nil	nil	trace	trace	150	200	nil	2	nil	nil

Each figure represents an average of duplicate treatments

Table 32. V. canadense. Seasonal variation of soil treatment pH with plants grown from (a) February 1, 1958 to November 1, 1958, and (b) March 1, 1958 to November 1, 1958

Treatments	Dates			
	April 2, 1958		November 1, 1958	
	a	b	a	b
1	3.3	3.3	3.4	3.3
2	4.8	4.8	5.1	5.2
3	5.4	5.6	5.9	5.7
4	7.8	7.4	8.0	8.0
5	8.3	7.9	8.3	8.5

Each figure represents an average of duplicate treatments

Table 33. V. canadense. Linear growth in cm. of stems during the 1958 growing season. Plants brought under greenhouse conditions on (a) February 1, 1958 and (b) March 1, 1958

Treatments	Total Linear Growth	
	a	b
1	19.0	11.0
2	73.0	31.0
3	9.5	7.5
4	2.0	4.0
5	4.0	

Each figure represents an average of duplicate treatments

Table 34. Soil analysis in p.p.m. of amended soil treatments. Analysis carried out on February 16, 1958 (1) and November 1, 1958 (2)

Treatments	NO_3		NH_4		P		K		Al		Fe		Ca		Mg		SO_4	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	2	trace	6	8	7	8	10	16	1	1	1	1	25	30	nil	1	140	155
2	5	trace	2	2	11	13	7	14	nil	trace	trace	1	40	25	nil	2	28	20
3	10	6	trace	trace	13	12	3	14	nil	trace	trace	1	37	60	nil	3	nil	nil
4	9	8	trace	trace	9	7	8	15	nil	trace	trace	1	110	200	nil	3	nil	nil
5	7	6	trace	trace	7	4	7	13	nil	trace	trace	1	180	200	nil	4	nil	nil

Each figure represents an average of the duplicate treatments

Table 35. Soil analysis in p.p.m. of amended soil treatments. Analysis carried on March 7, 1958 (1) and November 1, 1958 (2)

Treatments	NO_3		NH_4		P		K		Al		Fe		Ca		Mg		SO_4	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	1	trace	6	9	9	9	9	5	1	trace	2	1	35	30	nil	2	150	200
2	3	trace	1	4	10	15	7	10	nil	trace	trace	trace	45	35	nil	3	35	135
3	11	8	trace	1	13	12	5	11	nil	trace	trace	1	40	55	nil	4	nil	nil
4	11	8	trace	trace	11	9	7	13	nil	trace	trace	trace	170	200	nil	4	nil	nil
5	8	5	trace	nil	6	9	8	11	nil	nil	nil	nil	180	200	nil	4	nil	nil

Each figure represents an average of the duplicate treatments

Table 36. *V. canadense*. Oven-dry weight in gms. of roots, rhizomes and shoots of plants grown from (a) February 1, 1958 to November 1, 1958 and (b) March 1, 1958 to November 1, 1958

Treatments		Roots	Rhizomes	Shoots	Total
1	a	1.0	2.0	2.5	5.5
	b	0.5	2.0	2.5	5.0
2	a	1.5	5.0	6.5	13.0
	b	1.0	5.0	5.5	11.5
3	a	0.5	1.5	1.5	3.5
	b	0.3	1.0	2.0	3.3
4	a	0.1	1.0	0.5	1.6
	b	0.1	1.5	0.5	2.1
5	a	0.1	1.0	0.3	1.4
	b				

Each figure represents an average of duplicate treatments

Table 37. Soil analysis in p.p.m. of the amended soil treatments. Analysis carried out on February 9, 1957 (1) and November 1, 1958 (2)

Treatments	NO_3		NH_4		P		K		Al		Fe		Ca		Mg		SO_4	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	nil	trace	4	4	2	8	3	5	1	trace	trace	1	nil	20	trace	trace	45	105
2	nil	trace	6	2	2	13	5	10	nil	nil	trace	1	nil	25	trace	2	15	40
3	trace	trace	5	2	1	14	8	11	trace	trace	trace	trace	60	40	trace	1	nil	nil
4	2	4	3	1	1	11	7	11	trace	nil	trace	trace	110	155	trace	2	nil	nil
5	4	6	trace	trace	2	9	5	11	nil	nil	trace	trace	150	190	trace	2	nil	nil

Each figure represents an average of the duplicate treatments

Table 38. Soil analysis in p.p.m. of the amended soil treatments. Analysis carried out on March 7, 1957 (1) and November 1, 1958 (2)

Treatments	NO_3		NH_4		P		K		Al		Fe		Ca		Mg		SO_4	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	nil	trace	4	trace	3	12	4	8	1	trace	trace	1	nil	15	nil	2	45	100
2	nil	trace	6	trace	3	13	5	8	trace	trace	trace	1	nil	30	nil	4	40	65
3	trace	1	5	trace	3	10	6	12	trace	nil	trace	trace	60	120	nil	4	nil	nil
4	3	4	6	trace	3	13	7	10	nil	nil	trace	trace	100	160	nil	4	nil	nil
5	4	5	6	trace	3	14	6	13	nil	nil	nil	trace	150	200	nil	4	nil	nil

Each figure represents an average of the duplicate treatments

Table 39. V. vitis-idaea var. minus. Seasonal variation of soil treatment pH with plants grown from (a) February 1, 1958 and (b) March 1, 1958 to November 1, 1958

Treatments		Dates	
		April 2, 1958	November 1, 1958
1	a	3.3	3.5
	b	3.3	3.3
2	a	4.7	4.6
	b	4.8	5.0
3	a	5.5	5.8
	b	5.6	5.7
4	a	7.6	7.8
	b	7.5	8.1
5	a	8.3	8.2
	b	8.0	8.4

Each figure represents an average of duplicate treatments

Table 40. Soil analysis in p.p.m. of the amended soil treatments. Analysis carried out on February 9, 1958 (1) and November 1, 1958 (2)

Treatments	NO_3		NH_4		P		K		Al		Fe		Ca		Mg		SO_4	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	1	nil	6	8	7	8	9	13	1	trace	1	2	25	20	trace	2	145	350
2	2	trace	4	13	11	12	7	10	trace	trace	2	3	40	45	trace	2	40	110
3	8	5	trace	trace	11	9	6	11	nil	nil	trace	trace	45	65	trace	3	nil	nil
4	8	5	nil	trace	9	8	8	8	nil	nil	1	trace	175	200	trace	3	nil	nil
5	7	12	nil	nil	8	5	8	11	nil	nil	trace	trace	180	200	trace	2	nil	nil

Each figure represents an average of the duplicate determinations

Table 41. Soil analysis in p.p.m. of the amended soil treatments. Analysis carried out on March 5, 1958 (1) and November 1, 1958 (2)

Treatments	NO_3		NH_4		P		K		Al		Fe		Ca		Mg		SO_4	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	trace	nil	6	8	8	8	9	11	1	trace	1	2	25	20	nil	3	140	165
2	2	trace	4	13	12	11	8	10	trace	trace	2	3	40	45	trace	2	75	70
3	8	5	trace	trace	11	9	6	11	trace	nil	trace	2	45	65	1	2	nil	nil
4	8	5	nil	nil	9	8	7	8	nil	trace	1	1	175	200	trace	1	nil	nil
5	7	12	nil	nil	9	5	8	11	trace	trace	trace	2	180	200	trace	2	nil	nil

Each figure represents an average of duplicate treatments

Table 42. V. vitis-idaea var. minus. Total number of active shoots after one growing season. (a) Plants brought to greenhouse conditions on February 1, 1958. (b) Plants brought to greenhouse conditions on March 1, 1958

Treatment	1		2		3		4		5	
	a	b	a	b	a	b	a	b	a	b
Number of shoots	49	9	69	68	28	57	11	15	13	2

Each figure represents an average of duplicate treatments

Table 43. Oven-dry weight in gms. of V. vitis-idaea var. minus roots, rhizomes, and shoots of plants grown from (a) February 1, 1958 to November 1, 1958 and (b) March 1, 1958 to November 1, 1958

Treatment	1		2		3		4		5	
	a	b	a	b	a	b	a	b	a	b
Roots	0.5	0.3	1.0	1.5	0.5	0.7	0.1	0.3	0.1	0.1
Rhizomes	2.0	1.0	2.0	2.0	1.0	1.5	0.5	0.7	0.7	0.1
Shoots	1.5	0.7	3.0	3.0	1.0	2.5	0.1	0.6	0.5	0.1
Total	4.0	2.0	6.0	6.5	2.5	4.7	0.7	1.6	1.3	0.3

Each figure represents an average of duplicate treatments

Table 44. V. canadense. Shoot growth* during the 1956 growing season at sites 1 to 6

Sites	Shoots		Dates				
		June 8	June 22	July 10	July 25	August 10	August 28
1	a	Dormant bud	0.5	0.6	°0.7	0.9x	0.9x
	b	Dormant bud	1.4	1.5	°1.5	1.5x	1.5x
	c	Dormant bud	0.8	0.8	°0.8	0.8	0.8
2	a	Dormant bud	1.0	1.6	°1.7	1.8x	1.8
	b	Dormant bud	2.0	2.0	°2.0	2.0x	2.0
	c	Dormant bud	0.5	1.6	1.6	1.7x	1.7
3	a	Dormant bud	2.0	2.1	°2.1	2.1x	2.1
	b	Dormant bud	1.5	1.5	1.5	1.7x	1.7
	c	Dormant bud	3.2	°3.2	3.2	3.2	3.2x
4	a	Dormant bud	1.0	1.4	°1.4	1.4x	1.4
	b	Dormant bud	0.8	1.1	°1.1	1.6x	1.6
	c	Dormant bud	1.0	1.0	°1.0	1.0	1.0
5	a	Dormant bud	0.3	1.0	1.2	1.3x	1.3x
	b	Dormant bud	0.8	1.2	1.5	°1.5	1.5x
	c	Dormant bud	1.2	1.5	°1.5	1.5x	1.5
6	a	Dormant bud	3.0	3.5	°3.5	°3.5x	3.5x
	b	Dormant bud	1.0	1.5	1.5	1.5x	1.5
	c	Dormant bud	1.6	1.7	1.7	1.8	1.8

* measured in cms.

x date that the terminal bud was completely developed

° date of observation of the death of the terminal growing shoot tip

Table 45. *V. canadense*. Shoot growth* during the 1957 growing season at sites 1 to 6

Sites	Shoots	Dates							
		May 22	June 6	June 19	July 2	July 15	August 2	August 16	August 31
1	a	nil	0.9	0.9	0.9	0.9	1.0	°1.2x	1.2
	b	nil	0.9	1.0	1.1	1.2	1.2	°1.3x	1.3
	c	nil	0.8	0.8	0.8	0.8	1.2	°1.4x	1.4
2	a	0.4	2.4	2.8	2.8	2.8	2.8	2.9x	2.9
	b	nil	0.7	0.8	0.8	0.9	°1.0	1.2x	1.2
	c	nil	0.8	0.8	0.9	1.1	°1.1	1.2	1.2
3	a	0.2	2.4	3.1	3.7	3.7	3.9	4.0	4.2x
	b	nil	0.9	1.0	1.5	1.5	2.4	°2.4x	2.4
	c	nil	2.8	2.9	3.2	3.2	3.2	°3.3	3.3
4	a	0.3	1.4	1.6	2.3	2.6	°2.6	°2.7x	2.7
	b	nil	1.1	1.2	2.4	2.6	°2.6	2.7x	2.7
	c	nil	0.3	0.4	0.5	0.5	°0.6	0.7x	0.7
5	a	nil	0.5	0.5	0.5	0.6	°0.6	0.6x	0.6x
	b	nil	0.6	0.8	1.4	1.4	°1.5	1.6x	1.6
	c	0.2	1.2	1.3	1.5	1.5	°1.5	1.5x	1.5
6	a	0.3	1.4	1.4	1.4	1.4	1.4	°1.5x	1.5
	b	nil	1.0	1.2	1.3	1.4	1.5	°2.1x	2.1
	c	0.5	2.2	2.2	2.2	2.2	2.2	2.3	2.3

* measured in cms.

x date terminal bud completely developed

° date of observation of the death of the terminal shoot tip

Table 46. V. canadense. Fruit size* during the 1956 growing season at sites 1 to 6

Sites	Fruits	Dates					
		June 8	June 22	July 10	July 25	August 10	August 28
1	a	Dormant bud	Flowering	0.3	0.5		
	b	Dormant bud	Flowering	0.3	0.6	0.8x	
	c	Dormant bud	Flowering	0.3	0.5	0.5	0.6x
2	a	Dormant bud	0.1	0.4	0.5	0.6	0.8x
	b	Dormant bud	0.2	0.5	0.5	0.7	0.8x
	c	Dormant bud	Flowering	0.4	0.4	0.5	0.7
3	a	Dormant bud	Flowering	0.3	0.7	0.8x	0.8x
	b	Dormant bud	Flowering	0.3	0.5	0.6	0.7x
	c	Dormant bud	Flowering	0.3	0.4	0.4	0.7
4	a	Dormant bud	Flowering	0.3	0.5	0.5	0.6x
	b	Dormant bud	Flowering	0.4	0.5	0.5x	0.6x
	c	Dormant bud	Flowering	0.3	0.4	0.7	0.8
5	a	Dormant bud	Flowering	0.4	0.5	0.5	0.8x
	b	Dormant bud	Flowering	0.3	0.4	0.4	0.7x
	c	Dormant bud	Flowering	0.3	0.4	0.5	0.7x
6	a	Dormant bud	Flowering	0.4	0.5	0.8x	0.8
	b	Dormant bud	Flowering	0.4	0.5	0.6x	0.7
	c	Dormant bud	0.1	0.4	0.5	0.8	0.9

* measured in cms.

x fruit showing complete blue coloration

Table 47. *V. canadense*. Fruit size* during the 1957 growing season at sites 1 to 6

Sites	Fruits		Dates					
		June 6	June 19	July 2	July 15	August 2	August 16	August 31
1	a	Flowering	0.3	0.3	0.4	0.4	0.5	0.6x
	b	Flowering	0.3	0.3	0.3	0.4	0.5x	0.6x
	c	Flowering	0.4	0.4	0.4	0.5	0.8	0.8
2	a	Flowering	0.4	0.4	0.4	0.4	0.6	0.8x
	b	Flowering	0.3	0.3	0.4	0.4	0.5	0.7x
	c	Flowering	0.4	0.4	0.4	0.5	0.7x	0.7
3	a	Flowering	0.5	0.5	0.5	0.7	0.8	0.8x
	b	Flowering	0.3	0.3	0.4	0.4	0.4	0.6x
	c	Flowering	0.4	0.5	0.5	0.6	0.7	0.7x
4	a	Flowering	0.3	0.4	0.5	0.5	0.7x	0.7x
	b	Flowering	0.3	0.3	0.4	0.5	0.5	0.6x
	c	Flowering	0.3	0.3	0.3	0.5	0.6	0.6
5	a	Flowering	0.3	0.4	0.4	0.5	0.6x	
	b	Flowering	0.3	0.4	0.4	0.5	0.7x	
	c	Flowering	0.3	0.4	0.4	0.5	0.7	
6	a	Flowering	0.3	0.3	0.3	0.4	0.7x	0.7x
	b	Flowering	0.3	0.3	0.3	0.4x	0.8x	
	c	Flowering	0.4	0.4	0.4	0.6x	0.6	

* measured in cms.

x fruit showing complete blue coloration

Table 48. V. vitis-idaea var. minus. Shoot growth* during the 1956 growing season at sites 1 to 5

Sites	Shoots	Dates					
		June 8	June 22	July 10	July 25	August 10	August 28
1	a	nil	1.5	1.5	1.5	1.5x	1.5
	b	nil	1.2	1.6	1.6	1.7x	1.7
	c	nil	0.5	1.2	1.4	1.5x	1.5
2	a	nil	2.8	2.8	2.8	2.8	2.9x
	b	nil	2.5	2.5	2.5	2.5	2.7x
	c	nil	2.5	2.5	2.5	2.5	2.6x
3	a	nil	0.5	1.7	1.7	o1.7x	1.7x
	b	nil	0.4	1.3	1.8	1.8	2.0x
	c	nil	1.2	3.3	3.3	3.3	3.4x
4	a	nil	1.0	1.0	2.2	2.3x	2.3
	b	nil	1.5	1.5	1.5	o1.6x	1.6
	c	nil	1.2	1.2	3.9	o3.9x	3.9
5	a	nil	1.0	1.0	1.4	1.4x	1.5x
	b	nil	0.1	1.0	1.2	1.3x	1.3
	c	nil	0.1	0.8	1.2	1.4	1.4

* measured in cms.

x date that the terminal bud was completely developed

o date of observation of the death of the terminal growing shoot tip

Table 49. V. vitis-idaea var. minus. Shoot growth* during the 1957 growing season at sites 1 to 5

Sites	Shoots	Dates							
		May 22	June 6	June 19	July 2	July 15	August 2	August 16	August 31
1	a	nil	nil	0.6	1.2	1.2	1.2	°1.2x	1.2
	b	nil	nil	nil	0.7	1.6	1.6	1.8x	1.8
	c	nil	nil	0.2	0.9	1.2	1.4	1.5	1.5
2	a	nil	nil	0.9	1.8	1.9	2.0	2.0x	2.1x
	b	nil	nil	0.4	1.6	1.6	1.6	1.7	1.7
	c	nil	nil	0.7	1.7	2.2	2.8	2.8x	2.8
3	a	nil	nil	0.2	0.8	1.0	1.3	1.4	1.5x
	b	nil	nil	0.3	1.1	1.8	1.9	2.0x	2.0
	c	nil	0.7	1.2	2.7	2.8	2.8	2.9	2.9
4	a	nil	0.5	1.1	1.1	1.2	1.2	1.2x	1.2
	b	nil	nil	1.4	2.7	2.7	2.7	°2.7x	2.7
	c	nil	nil	1.3	2.5	3.1	3.1	°3.1x	3.1
5	a	nil	nil	nil	0.9	1.5	1.5	°1.5x	1.5
	b	nil	nil	0.4	0.8	1.0	1.0	1.1x	1.1
	c	nil	nil	0.3	2.5	2.5	2.5	2.7x	2.7

* measured in cms.

x date terminal bud completely developed

° date of observation of the death of the terminal shoot tip

Table 50. *V. vitis-idaea* var. *minus*. Fruit size* during the 1956 growing season at sites 1 to 5

Sites	Fruits	Dates				
		June 22	July 10	July 25	August 10	August 28
1	a	Dormant bud	Flowering	0.3	0.6	0.8x
	b	Dormant bud	Flowering			
	c					
2	a	Flowering	0.2	0.5	0.6	0.7x
	b	Flowering	0.2	0.3	0.4	0.7x
	c	Dormant bud	Flowering	0.5	0.7	0.8x
3	a	Flowering	0.2	0.5	0.6	0.7x
	b	Flowering	0.1	0.5	0.6	0.7x
	c	Flowering	0.2	0.3	0.5	0.6x
4	a	Flowering	0.1	0.4	0.7	0.8x
	b	Flowering	0.1	0.4	0.5	0.6x
	c	Flowering				
5	a	Dormant bud	Flowering	0.2	0.4	0.7x
	b					
	c					

* measured in cms.

x fruit showing complete red coloration

Table 51. *V. vitis-idaea* var. *minus*. Fruit size* during the 1957 growing season at sites 1 to 5

Sites	Fruits	Dates						
		June 6	June 19	July 2	July 15	August 2	August 16	August 31
1	a	Dormant	Flowering	0.2	0.5	0.6	0.6	0.8x
	b	Dormant	Flowering					
	c	Dormant	Dormant	Flowering	0.2	0.5	0.6x	0.6
2	a	Dormant	Flowering	0.1	0.2	0.5	0.6	0.7x
	b	Dormant	Flowering	0.1	0.3	0.6	0.6	0.7x
	c	Dormant						
3	a	Dormant	Flowering	0.1	0.3	0.5	0.6x	0.6
	b	Dormant						
	c	Dormant	Flowering	0.2	0.2	0.5	0.6	0.6x
4	a	Dormant	Dormant	Flowering				
	b	Dormant	Dormant	Flowering	0.3	0.5	0.5	0.6x
	c	Dormant	Flowering	0.1	0.5	0.6	0.6	0.7x
5	a	Dormant	Dormant	Flowering	0.3	0.5	0.5	0.5x
	b	Dormant						
	c	Dormant	Flowering	0.1	0.3	0.5	0.6	0.6x

* measured in cms.

x fruit showing complete red coloration

Table 52. V. canadense. The number of surviving rhizome cuttings (based on a total of twenty-five per treatment) during 1957

Replicates	Plot Locations							
	Medium Elevation				Low Elevation			
	Treatments				Treatments			
	1	2	3	4	1	2	3	4
1	5	10	22	19	10	14	19	19
2	6	15	20	16	6	8	25	17
3	5	12	25	18	7	17	23	21
4	8	13	23	20	11	13	21	20
5	10	6	25	15	5	15	20	18
Means	7	11	23	18	8	13	22	19

Analysis of Variance

Source of Variation	df	ss	ms	F	5%
Total	39	1538.0			
Locations	1	6.5	6.5		
Treatments	3	1307.5	435.6	68.0*	2.88
Interaction L x T	3	18.0	6.0		
Error	32	206.0	6.4		

$L.S.D._{.05} = 3.3$

Table 53. V. canadense. Oven-dry weight in gms. of shoot growth during 1957

Replicates	Plot Locations							
	Medium Elevation				Low Elevation			
	Treatments				Treatments			
	1	2	3	4	1	2	3	4
1	0.6	0.7	0.9	0.8	0.8	0.7	0.6	0.8
2	0.4	0.4	1.0	0.7	0.5	0.7	1.0	0.5
3	0.3	0.6	0.6	0.7	0.6	0.8	0.8	0.7
4	0.5	0.5	0.7	0.4	0.3	0.9	0.8	0.9
5	0.4	0.9	0.6	0.4	0.3	0.6	1.0	0.8
Means	0.4	0.6	0.8	0.6	0.5	0.7	0.8	0.7

Each figure represents the average weight of shoot growth from 10 cuttings

Analysis of Variance

Source of Variation	df	ss	ms	F	5%
Total	39	1.5			
Locations	1	0.1			
Treatments	3	0.6	0.2	8.0*	2.88
Interaction L x T	3	0.0			
Error	32	0.8	0.025		

$L.S.D._{.05} = 0.2$

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